THE NEW CASTLE SPILL SITE
NEW CASTLE, DELAWARE

Final
Remedial Investigation
Volume I

5 May 1989

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FINAL
REMEDIAL INVESTIGATION REPORT
FOR
THE NEW CASTLE SPILL SITE
VOLUME I

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

The ERM Group

LIST OF APPENDICES

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

LIST OF FIGURES
(Continued)

EXECUTIVE SUMMARY

During the summer of 1977, tris(2-chloropropyl)-phosphate reportedly leaked from a drum in the drum storage area at Witco Company's New Castle facility, hereafter referred to as the New Castle Spill Site. The New Castle Spill Site is bordered on the south by the New Castle Board of Water and Light (NCBW&L) property, which at the time of the spill served as a water supply source for the City of New Castle.

In December 1982, the New Castle Spill Site was listed on EPA's National Priorities List. An Administrative Consent Order (ACO) was signed by both Witco Corporation and the Department of Natural Resources and Environmental Control (DNREC) in December 1987. The mutual objectives of the ACO were to: 1) determine fully the nature and extent of the threat to the public health, welfare or the environment caused by the release or threatened release of any hazardous wastes, substances, pollutants or contaminants from or onto the New Castle Spill Site, and 2) to evaluate alternatives for remedial action to prevent, mitigate or otherwise respond to or remedy the threat to public health or welfare or the environment. Environmental Resources Management, Inc. (ERM) was then contracted by Witco Corporation to prepare and submit a Work Plan for the Remedial Investigation/Feasibility Study (RI/FS) of the site to the DNREC. Following DNREC approval of the Work Plan, ERM began work at the New Castle Spill Site in February 1988.

The Remedial Investigation (RI) was performed to assess the nature, extent and magnitude of site-related contamination on the local ground water, soil, stream sediment, and surface water, and to provide a technical basis for remedial action at the New Castle Spill Site. The Work Plan for the RI was designed to augment the substantial body of existing data collected at the New Castle Spill Site since 1979 by various consultants.

The hydrogeologic investigation was designed to provide a thorough understanding of the hydrogeologic characteristics of the Columbia aquifer beneath the New Castle Spill Site. The hydrogeologic investigation included the installation of five ground water monitoring wells, a 6-inch pumping well, and the performance of a 24-hour pump test involving sustained pumping of the 6-inch pumping well while water levels in surrounding monitoring wells were continuously measured.

The Phase I ground water sampling effort involved the collection of ground water samples from five new and 12 existing ground water monitoring wells within the New Castle Spill Site study area during April 1988. Phase I ground water samples were analyzed for the following: tris(2-chloropropyl)-phosphate (tris), Target Compound List (TCL) volatiles and semivolatiles, total organic carbon (TOC), chemical oxygen demand (COD), pH, iron, and manganese. Phase II ground water samples were obtained in June 1988 to address data gaps identified by the Phase I analysis. These samples were analyzed for TCL volatiles and tris. The purpose of the ground water sampling was to characterize the nature, extent and magnitude of ground water contamination.

A subsurface soil sampling program was conducted to assess the vertical and horizontal extent of soil contamination in the vicinity of the potential source area. In this effort, continuous split spoon samples were taken to the water table at eight boring locations. Fifteen soil samples collected during March 1988 were submitted for analysis based on headspace readings and visual observations. The Phase I soil analyses were conducted to detect tris and TCL volatiles and semivolatiles. One additional sample, collected in June 1988 as part of the Phase II groundwater and soil sampling, was submitted for tris analysis.

An investigation of the wetlands adjacent to the western boundary of the study area was also conducted to determine if ground water potentially contaminated with tris and pumped from the NCBW&L gallery after the spill affected the wetlands. This investigation included delineation of the wetlands based on U.S. Fish and Wildlife Service National Wetland Inventory Maps and the collection of surface water and sediment samples from six sampling stations. Phase I surface water was collected in March 1988 and analyzed for tris, pH, and conductivity, while Phase I sediments were analyzed for tris, and grain size. Phase II surface water samples were collected in November 1988 and submitted for tris, TCE, total and dissolved iron and manganese, and salinity while Phase II sediments were analyzed for tris, TCE, percent moisture, grain size distribution, TOC, and field pH. These analyses, in addition to a macroinvertebrate study were conducted to assess the impact of the New Castle Spill Site on the adjacent wetland community.

Results of the hydrogeologic investigation indicate that the unconfined Columbia aquifer which underlies the New Castle Spill Site is composed primarily of a medium grained sand with an average transmissivity of 60,000 gal/day/ft and approximate saturated thickness of 23.5 feet. In the northern part of the study area, ground water flows in a northerly direction at a rate of 1 ft/day, while in the southern part of the study area, ground water flows in a westerly direction toward the marsh at a rate of 0.5 ft/day. Ground water within the study area is not tidally influenced.

The drilling program defined three distinct stratigraphic units across the study area: a surficial layer consisting of a variable sequence of clay, silty clay and silty sand; an intermediate layer (i.e., Columbia aquifer) consisting of medium grained sand; and a very dense, stiff clay layer at an average depth of 30 feet which designates the top of the underlying Potomac Formation. Vertical permeability tests were conducted on 5 Shelby tube samples of the clay and the results ranged from 1.48×10^{-8} to 4.83×10^{-8} cm/sec. A minimum of 5-feet of this material was encountered in each of the newly installed wells and is considered to be continuous across the study area. Information gathered from other wells within the study area define this clay as the top of an 85-foot-thick sequence of clay, silty clay, silts and sands which serve to isolate the Columbia aquifer from the underlying Upper Potomac aquifer.

Under static ground water conditions, 160 years are required for the movement of ground water to a depth of 1-foot into this clay. Likewise, movement of ground water to a depth of 10-feet into the clay would require 1,600 years. Additional information supporting a lack of aquifer interconnection includes; pump test information, and water levels in the Upper Potomac aquifer.

The pump test of the Upper Potomac aquifer, conducted in April-May 1986 yields data from well PH that indicates a typical confined response to pumping. Additionally, the storage coefficient calculated for the Upper Potomac from this test (0.00011) is indicative of a confined system. A final line of evidence, with respect to the April-May pump test, is the stability of the water levels in the Columbia aquifer during the first 12 hours of the test, and prior to the recharge resulting from the ponding of discharge water on the surface. Stability of the water levels from those wells in close proximity to the pumping well (PW-11) demonstrate a lack of interconnection between the Columbia and Potomac aquifers.

The average depth to the top of the confining clay is approximately 30-feet BLS. As evidenced by depth-to-water measurements obtained from well PH, both recently and in 1986, the potentiometric surface of the Upper Potomac aquifer extends approximately 15 feet above its confining layer. These artesian conditions are supportive of the clays continuity throughout the study area.

The occurrence and distribution of tris, which was detected in 9 of 15 soil samples, at concentrations ranging from 54 to 11,740 ug/kg, reflects higher concentrations in those soils of the recognized spill source area. Within the spill source area, tris was detected to a depth of 8 feet. However, the mobility of tris is limited both by its preference to adsorb onto the soil matrix and by the fact that the area of highest tris concentration in the soils is presently capped by asphalt and concrete.

Therefore, additional leaching of tris into the ground water from a "washing effect" by infiltrating rain water is restricted.

TCE was conspicuously absent from all soil samples submitted for analysis as part of this study. It is therefore concluded that the presence of TCE in ground water originates from an upgradient and off-site source and therefore can not be attributed to past activities at the New Castle Spill Site.

The trace and non-quantifiable concentrations of Polynuclear Aromatic Hydrocarbons (PAH's) in soils of the spill source area had a tendency to decrease with depth and are likely derived from asphalt paving.

Detectable and quantifiable concentrations of tris, ranging from 17.1 to 110,000 ug/l, were identified in 7 of 17 wells sampled. The distribution of tris in the Columbia aquifer is consistent with the spill source area, and reflects a reduced mobility by its occurrence primarily in the upper 10-feet of the aquifer. This is evidenced by higher tris concentrations in the "OB" series wells, screened at the top of the Columbia aquifer, in contrast to the "MW" series wells, screened at the base of the same aquifer. In addition to tris, TCE was the other predominant compound identified in the 17 ground water samples collected.

The distribution of TCE, which was detected in 8 of 17 samples, ranged in concentration from 1 to 120 ug/l. The absence of this compound in the soil samples submitted for analysis indicate an upgradient and off-site source for TCE. The occurrence and distribution of TCE in the ground water samples suggests that this off-site source may exist either to the south or east of the New Castle Spill Site.

The New Castle Spill Site is bordered to the west by wetlands that support a diverse flora and associated wildlife community. Samples collected from within the wetlands possessed quantifiable concentrations of tris ranging from none detected to 42 ug/l in surface water while wetlands sediments yielded results of none-detected. Confirmatory sampling conducted in June 1988 yielded order-of-magnitude lower results for surface water, while 2 sediment samples contained quantifiable tris concentrations of 300 and 402 ug/kg. However, based on investigations conducted as part of this study, it is concluded that potential receptors dwelling within the wetland, such as macroinvertebrates, fish, birds and mammals, are not affected by the New Castle Spill Site.

An additional investigation involving the identification of all wells within a 2 mile radius north of the New Castle Spill Site, and 1 mile south of the New Castle Spill Site, indicate that there are not any ground water withdrawls for either domestic or municipal purposes from the unconfined Columbia aquifer.

SECTION 1

INTRODUCTION

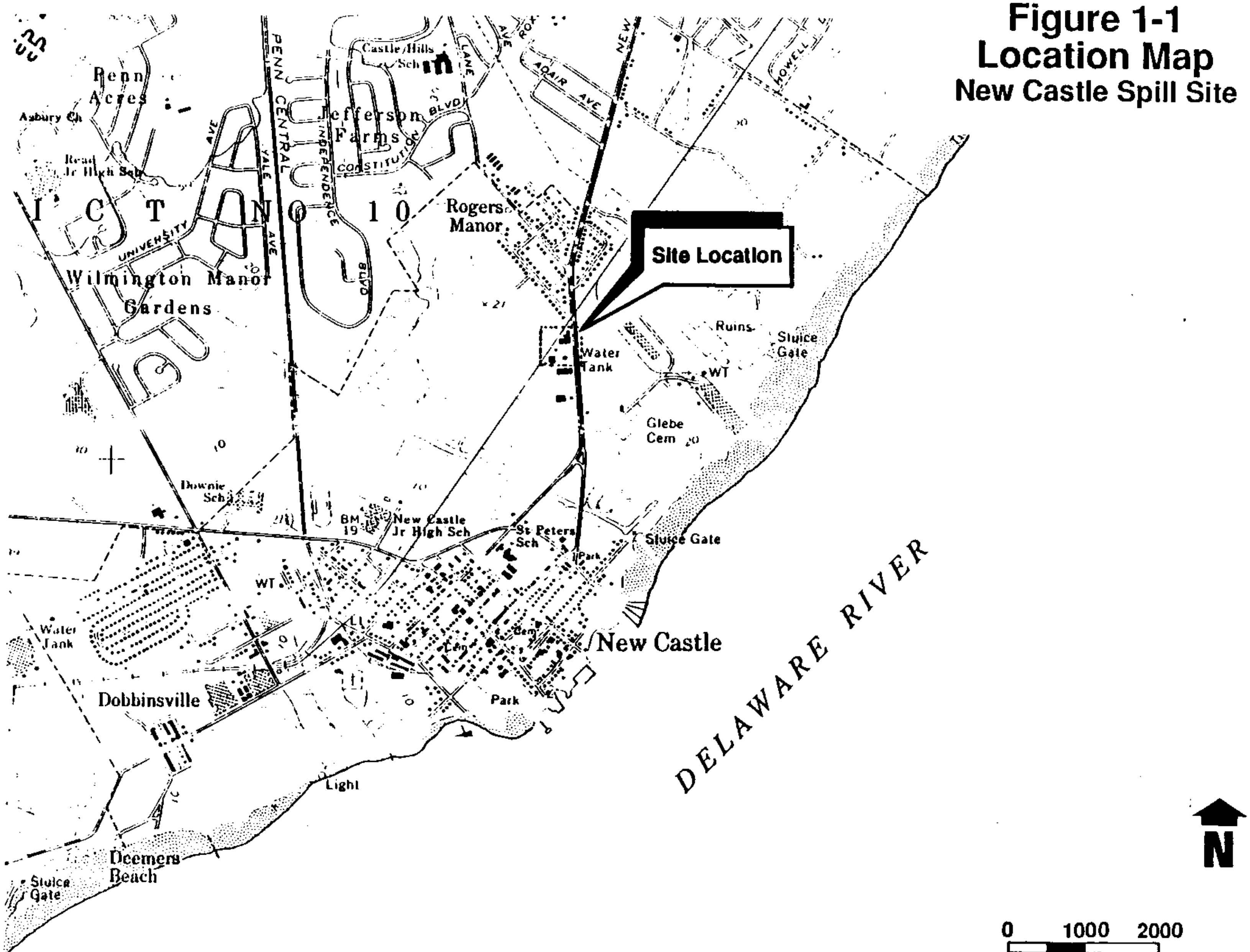
1.1 Site Description

The study area consists of two properties: the Witco Corporation property (New Castle Spill Site) and the adjacent New Castle Board of Water and Light (NCBW&L) property. Both properties cover a combined area of approximately 6 acres and are located approximately 0.5 miles west of the Delaware River within the city limits of the town of New Castle, Delaware (Figure 1-1). The study area is accessible via Wilmington Avenue (i.e., Route 9) as shown in Figure 1-2.

The New Castle Spill Site was once used by Witco Corporation to manufacture materials used in the production of plastic foams. The plant used prepolymers as feedstocks and generated spent solvents as waste products. Both raw materials and waste products were stored in 55-gallon drums on a concrete pad adjacent to the NCBW&L property. Additionally, waste products generated by Witco's quality control laboratory were also stored with these other materials. Section 1.2 presents a detailed description of past industrial operations. A list of chemicals handled at the New Castle Spill Site is presented in Appendix A. A review of this list indicates that trichloroethene (TCE) was not handled on site.

The NCBW&L property was once used as a treatment facility designed to process water extracted both from an on-site production well and from a shallow infiltration gallery. The infiltration gallery was designed to collect water from the water

Figure 1-1
Location Map
New Castle Spill Site



Source: USGS 7.5 Min. Topographic Quadrangle; Wilmington South, DE-NJ

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Figure 1-2
New Castle Spill Site Map

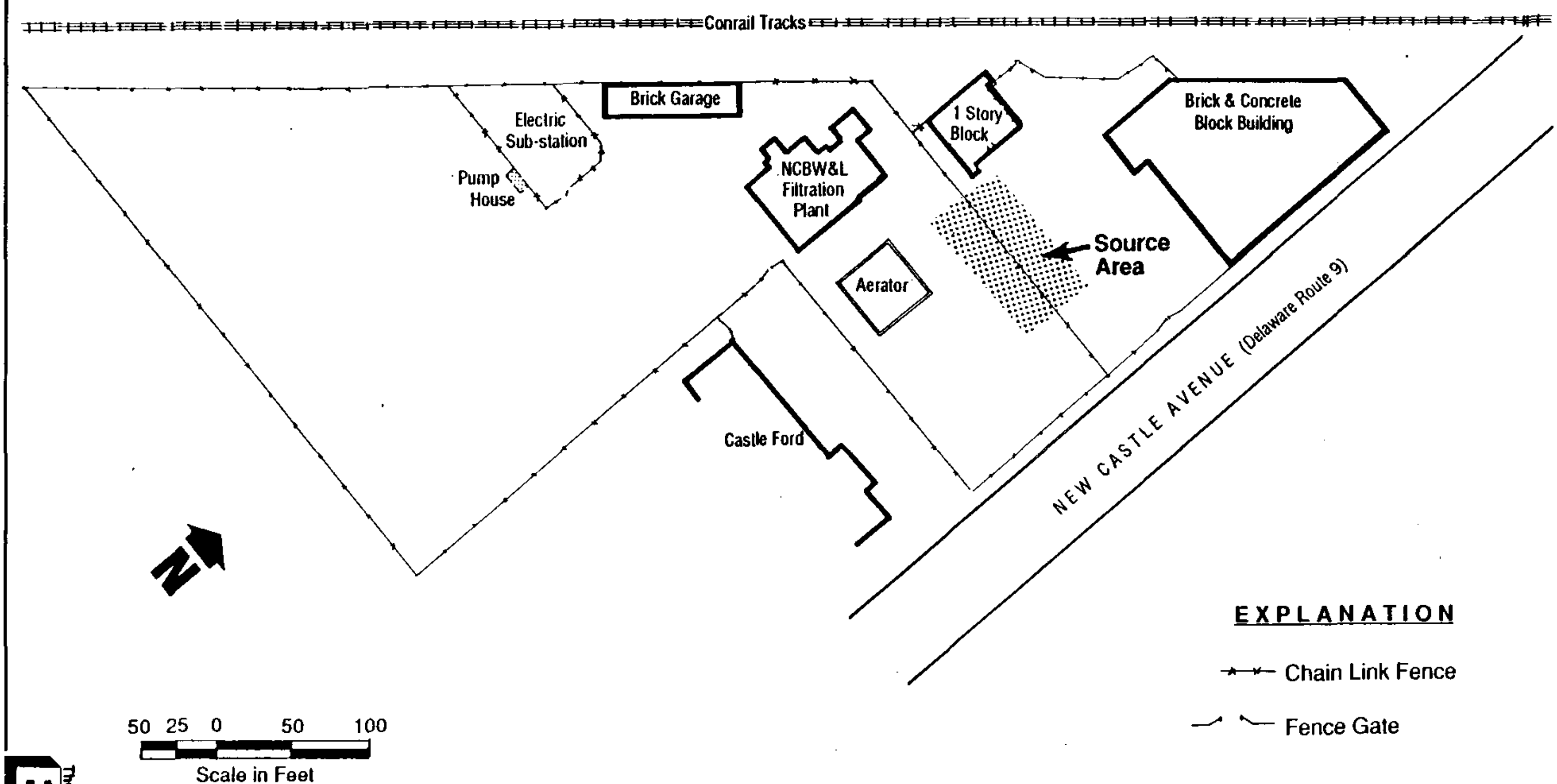

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table aquifer (i.e., Columbia aquifer), while production well PW-11 pumped water from the underlying Potomac sediments. The NCBW&L's consultant rated the capacity of the treatment plant at 1,000,000 gallons per day (gpd) and the gallery system at 618,000 gpd. Since 1960 the water from the shallow gallery system had low pH and high levels of iron (500 mg/l) and manganese (100 mg/l). In 1961, inorganic analysis indicated ground water at a pH of 3, with iron concentrations ranging from 50-75 mg/l and a manganese concentration of 10 mg/l. Analysis of ground water in 1976 indicated that pH values had risen to 4.5 standard units while iron concentrations had decreased in concentration to 2 mg/l. The Chicago Bridge and Iron Company, located approximately 2,250 feet to the southeast, was suspected to be the source. In light of the low ph and high iron and manganese levels, the water table aquifer was of questionable quality prior to the leak at the New Castle Spill Site. A letter from Mr. Richard Howell of the Division of Public Health dated 19 January 1979 to Mr. Edward Murphy of the Board of Water and Light Commissioners reported that the shallow gallery system was improperly constructed and protected. Mr. Michael Apgar of DNREC in a 12 April 1979 letter to the legal firm of Cooch and Taylor stated that from the comments contained in Mr. Howell's letter it appeared questionable whether approval of the gallery system would be granted even if the organic compounds detected were cleaned up. The shallow gallery system has not been used since 1978. Production well PW-11, located on NCBW&L property, was also taken out of service when the NCBW&L was refused an NPDES permit to discharge backwash water containing elevated concentrations of iron from their treatment facility to the adjacent wetlands.

1.2 Site History

Two manufacturing processes took place at the New Castle Spill Site. The largest was a blending operation of polyether polyols with amine and/or tin catalysts plus fluorocarbon-11, flame retardants (if desired) and silicone surfactant. The second process was the formation of a prepolymer from the reaction of a polyether polyol with diisocyanate.

During the summer of 1977, an NCBW&L employee noticed a patch of dead grass on the NCBW&L property. This area of dead grass was located next to the drum storage area on the adjacent Witco property. A subsequent investigation, performed by Witco, detected the presence of tris(2-chloropropyl)-phosphate (tris) in the soils beneath the dead grass. The approximate location of the spill area and nearest residential area are shown on Figure 1-2. The quantity of tris spilled was estimated to be 4 to 5 drums. Shortly following the spill, ground water potentially contaminated with tris was pumped from the gallery system and discharged to the adjacent wetlands under the direction of the DNREC. Information provided by the NCBW&L indicated that water was pumped from the gallery system from 13 December 1977 through 31 May 1978.

1.3 Previous Investigations

The initial response action to the spill was taken by the DNREC during 1977 after the spill was reported. DNREC enlisted the U.S. EPA to assist in the identification of the presence and toxicity of tris in January, 1978. At that time, tris was detected in ground water from the Columbia aquifer at 3 ug/l or less.

To date, a total of ten field investigations and eight summary reports have been completed for the New Castle Spill Site and the adjacent NCBW&L property. A preliminary assessment has also been conducted at the nearby Chicago Bridge and Iron property located approximately 1,000 feet east of the Witco facility. The documents produced from these efforts are as follows:

1. "Groundwater Evaluation, Chemical Intrusion Investigations at Wilmington Avenue Water Filtration Plant, City of New Castle, Board of Water and Light Commissions, Phase II," May 1980, by Duffield Associates.

2. "Potential Hazardous Waste Site Identification and Preliminary Assessment," June 1980, U.S. EPA.

3. "A Chemical Intrusion Study of Shallow Aquifer Water Sources at New Castle Water Filtration Plant on Wilmington Avenue", July 1980, by Duffield Associates, Inc. and Betz, Converse, Murdoch, Inc.

4. "Groundwater Evaluation Phase III - Chemical Intrusion Investigation," September 1980, by Duffield Associates, Inc.

5. "Site Inspection Report," September 1980, U.S. EPA.

6. Memo from NEIC, November 1980, Wm. Stager.

7. "Chemical Hazard Information Profile, Draft Report, Tris(1,3-dichloro-2-propanol)Phosphate," August 1981, CAS No. 13674-87-8.

8. "Site Inspection Report of Witco Chemical Company, New Castle, Delaware," November 1981, U.S. EPA.

9. "Unit Risk Estimate for Tris(2,3-Dibromo Propyl)Phosphate," December 1981, Robert E. McGaughy, Acting Director CAG, U.S. EPA.

10. "Hazard Ranking System Model - Draft Report," April 1982, U.S. EPA.

11. "Hazard Ranking System Model," July 1982, U.S. EPA.

12. "Field Trip Report," August 1982, U.S. EPA.

13. "Groundwater Well Sampling at Witco - Isofoam Division, Wilmington, Delaware," 18 January 1983, by Princeton Aqua Science.

14. "Soil and Groundwater Sampling at Witco - Isofoam Division, Wilmington, Delaware", June 1983, by Princeton Aqua Science.

15. "Hydrogeologic Evaluation of the Witco Chemical Company New Castle Water Works Matter at New Castle, Delaware," November 1983, by Environmental Resources Management, Inc.

16. New Castle Water and Light Commission Sampling Project, January 1984, by Ecology and Environment, Inc.

17. Mitre Model of Witco Chemical Company, New Castle, Delaware, Un-Dated, U.S. EPA.

18. "New Castle Spill, Technical Review of Documents, Final Reports," February 1986, by Planning Research Corporation (PRC) for U.S. EPA.

19. "A Preliminary Assessment of Chicago Bridge and Iron," EPA No. DE-38, Emergency and Remedial Response Information System, July 1984 (Chicago Bridge & Iron report ERRIS).

Review and evaluation of the information included in the aforementioned previous investigations and summary reports identified the following issues of concern at the New Castle Spill Site:

- the occurrence of tris in ground water,

- the occurrence of organic compounds in ground water,

- the occurrence of tris in soils, and

- aquifer interconnection.

1.3.1 Ground Water Quality of the Water Table Aquifer

The ground water associated with the study area has been sampled a total of 12 times since 1978. The samplings include a series of 24 monitoring wells (Figure 1-3) that are screened in the shallow water table aquifer (i.e., Columbia aquifer) and production well No. 11, that is screened in the upper sandy unit of the deep aquifer (i.e., Potomac Formation). A comprehensive summary of the previous sampling events have been tabulated and provided in the RI/FS Work Plan prepared by ERM (1988).

Tris Occurrence in Ground Water

Tris has been detected within the shallow aquifer in concentrations ranging from none detected to greater than 100,000 ug/l. Samples collected from the deep aquifer revealed the

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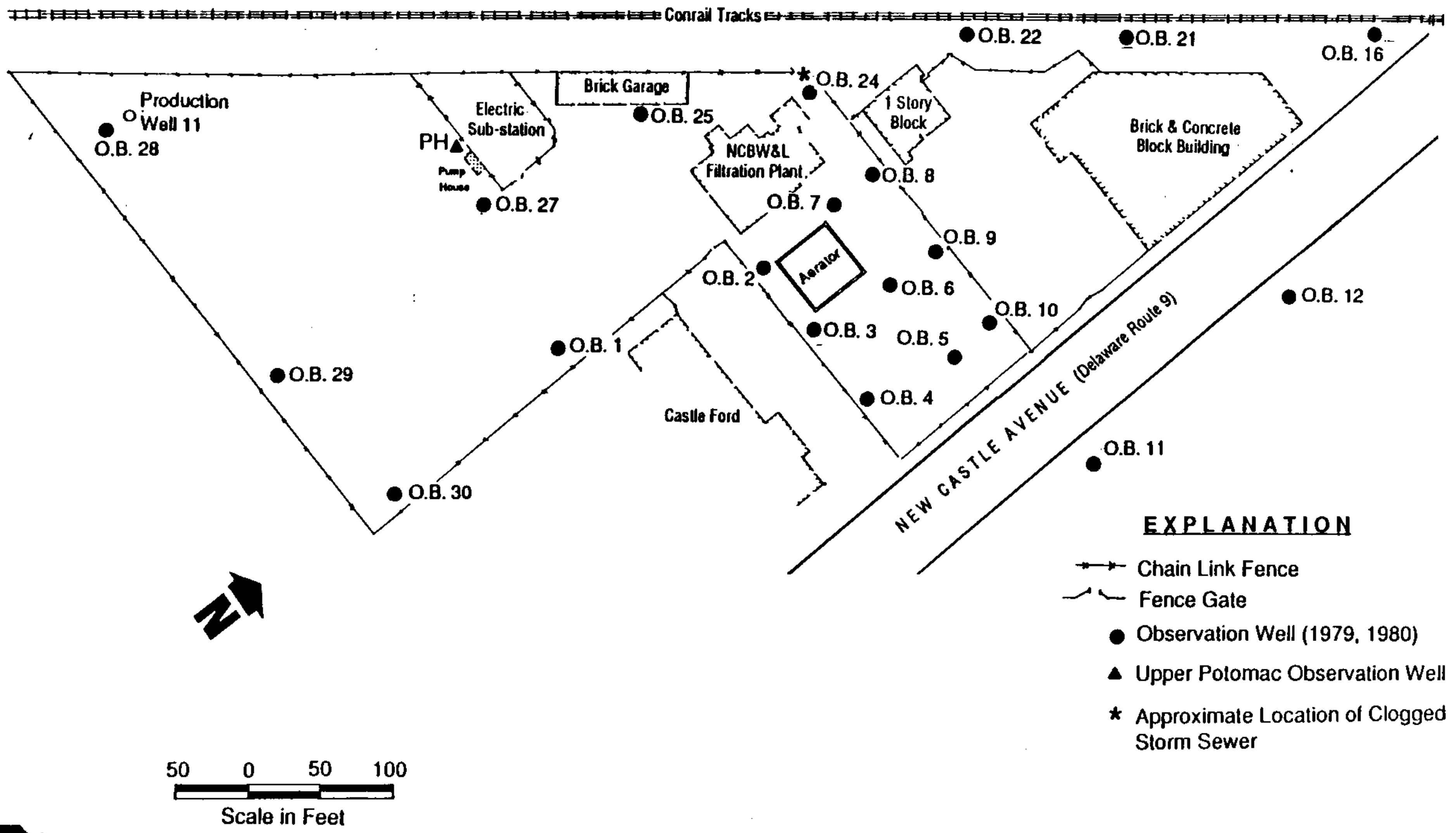
Figure 1-3
Existing Well Locations
New Castle Spill Site



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presence of tris in 1978 at 0.03 ug/l. Tris was not detected in the deep aquifer during five sampling events conducted between 1978 and 1983. It is important to note that the 1978 analysis for tris was conducted with a detection limit of less than 7 ug/l, while all analysis subsequent to 1978 was conducted with a tris detection limit of 7 ug/l or greater. Therefore, if tris had been present at concentrations less than the 7 ug/l detection limit, this compound would have been reported as "NONE DETECTED" in all analysis subsequent to 1978.

Shallow ground water has also been sampled for priority pollutant volatile organic compounds (VOCs), and semivolatile contaminants with the exception of acrolein, acrylonitrile, and tetrachlorodibenzo-p-dioxins.

Compounds other than tris that have been detected in the shallow aquifer samples fall into three classes as follows:

1. Those which were found at detectable concentrations in the early part of the sampling record, but were found at only trace levels (5 ug/l) or below the detection limit, in subsequent samplings.

2. Those which were detected, but have a limited sampling record of 1 or 2 samplings.

3. Those which have been detected over multiple samplings at concentrations above trace or detection limits.

Several compounds were detected during the initial sampling events, but were not found above trace levels or above detection limits in subsequent monitoring events. These compounds include ethylbenzene, methylene chloride, tetrachloroethene (PCE), and toluene.

Compounds that were detected but have a sampling record that is limited to one or two monitoring events include acetone, 2-hexanone, 4-methyl-1-2-pentanone, dichlorodifluoromethane, xylene, pentachlorophenol, 2-methyl-4,6-dinitrophenol, and bis(2-ethylhexyl)phthalate.

Two compounds other than tris have been monitored and consistently detected at greater than trace amounts over the sampling record. These compounds are TCE and trichlorofluoromethane.

TCE has been tested for in 12 samplings conducted between 1978 and 1984. In the early samplings, the compound was detected in 12 of the monitoring wells, ranging from less than 1 to 75 ug/l. In a later sampling (June 1984), the range in concentration had decreased, ranging from less than detectable to 20 ug/l. Only 3 of the 13 wells sampled at this time yielded samples with greater than trace amounts (5 ug/l) of TCE. These include wells OB-3, OB-21, and OB-22. Well OB-3 is located along the north fence line between Castle Ford and the NCBW&L property, whereas wells OB-21 and OB-22 are located along the railroad right-of-way. TCE is a compound found in solvents that could have been associated with Castle Ford or Conrail. The Witco property is less suspect as a source because there was no significant TCE found in the ground water in the spill source area.

Trichlorofluoromethane, a refrigerant and aerosol propellant, was analyzed in three samplings during 1983 and 1984. During 1983, this compound was detected at concentrations ranging from less than detectable to 356 ug/l in wells OB-8, OB-9, OB-16, OB-21, OB-23, and OB-24. A subsequent sampling, conducted in 1984, indicated that four additional wells, OB-2, OB-6, OB-7, and OB-22 also yielded samples with trichlorofluoromethane. These latter analyses conducted on samples collected in 1984 may not be representative because the analytical method used by the EPA provided an estimated value for this compound. However, these concentrations range from none detectable, in wells OB-5, OB-9 and OB-10, to an estimated concentration of 356 ug/l, in well OB-8, for the June 1984 sampling. In the May 1983 sampling, well OB-8, located in the tris spill source area, had the highest concentration of trichlorofluoromethane at 356 ug/l. The second highest concentration detected during this same sampling event (256 ug/l) was found in well OB-21 along the railroad right-of-way. However, the analytical work for all sampling in 1983 for trichlorofluoromethane is suspect because the two pairs of split samples taken yielded widely varied results.

1.3.2 Ground Water Quality for the Deep Aquifer

The NCBW&L deep production well (PW-11) has been sampled nine times since 1978 for priority pollutant organic compounds. Many of these compounds have been consistently reported as none detectable or less than detectable. The most pervasive contaminant in the upper aquifer, tris, was reported only once out of seven sampling events at a trace concentration (0.03 ug/l) in 1980. This value is suspect, however, as all detection limits reported by the various laboratories have been 7 ug/l or greater.

PCE and TCE were detected by BCM in February 1980 at concentrations of 41.1 and 13.6 ug/l, respectively. Neither compound, however, was detected above 1 ug/l in seven subsequent sampling events.

Bis(2-ethylhexyl)phthalate has been monitored in three samplings of production well PW-11. It was not detected in January 1983, but was reported at 274 ug/l in one of two different contractor samples in May 1983. The second of these samples reported a none detectable concentration, indicating a probable laboratory cross-contamination problem as the source of the 274 ug/l report.

1.3.3 Soil Sample Results

The soils associated with the New Castle Spill Site have been sampled three times since 1979. Samples have been collected within and around the tris spill area at depths ranging from 0 to 12 feet. Soil samples were analyzed for tris and priority pollutants, excluding the acid extractable and pesticide compounds. Compounds detected in soils are briefly discussed in the following paragraph; refer to the approved work plan for detailed data tables.

Tris, TCE, toluene, Di(n)butyl phthalate, and several base neutral compounds were detected in more than one soil boring. Tris concentrations in soil samples collected in the vicinity of the tris spill have ranged from less than 50 ug/kg to over 200,000 ug/kg. TCE concentrations in soil samples collected during previous investigations in the vicinity of the spill source area ranged from none detected in soil samples collected above a depth of 10 feet to a high of 2.9 ug/kg at a depth of 12 feet. The highest level of TCE (10.4 ug/kg) was detected in the soil sample from Boring CI-1, on the west side of the Ford dealer adjacent to NCBW&L, at a depth of 10.5 feet. The detection depth and the decreasing concentrations across the site indicated a probable off-site source for TCE. Toluene concentrations ranged from none detectable to 56 ug/kg. This compound was detected in two samples located along the Conrail tracks on the west side of the study area. The base neutral compounds detected are indicative of creosote treated railroad ties and asphalt construction products. The phthalate compound is considered suspect because it frequently occurs as a result of laboratory cross-contamination. Compounds detected in a single sample location included PCBs, PCE, and chloroform.

1.3.4 The Issue of Aquifer Interconnection

Sufficient information is available which demonstrates a lack of aquifer interconnection between the shallow Columbia aquifer and deep Potomac aquifer systems at the site. Four types of data, including: 1) site-specific cross-sections, 2) pump test data, 3) water quality data, and 4) vertical permeability testing of the clay demonstrate a lack of aquifer interconnection between the Columbia and Potomac systems.

1.3.4.1 Site Specific Cross-Section

The cross-section depicted in Figure 1-4 is generated from two on-site wells (PW-11 and Observation Well PH) completed within the Potomac Formation. Description of the materials encountered during the installation of these wells indicate that within the study area, the upper 20-30 feet consists of sand and gravel deposits of the Columbia Formation. These deposits are underlain by a sequence of clay, sandy clay, sand and gravel to an approximate depth of 110 feet. These materials serve to isolate the sand and gravel of the Upper Potomac aquifer, which is encountered at an approximate depth of 110 feet, from the surficial sands and gravels of the Columbia Formation. The vertical permeability of this confining layer is discussed in Section 1.3.4.4.

Additional evidence supporting the continuity of the confining layer is given by the potentiometric surface of the Upper Potomac aquifer as depicted in Figure 1-4. The approximate depth to this confining clay layer is 30 feet below land surface (BLS). Depth-to-water measurements obtained in March and April 1988 from well

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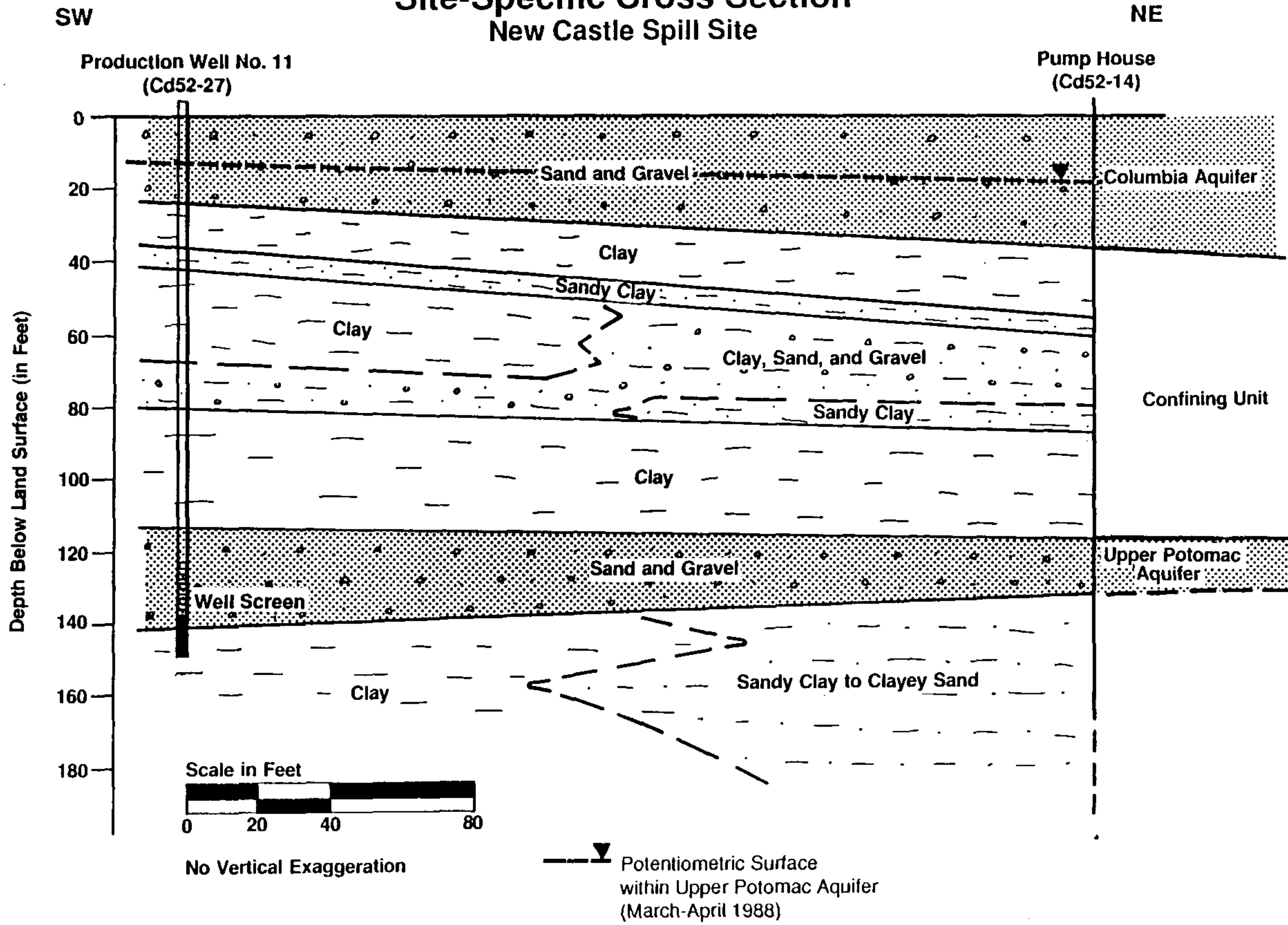
31003

Figure 1-4
Site-Specific Cross Section
New Castle Spill Site



PH, screened within the Upper Potomac aquifer, indicate the potentiometric surface extends approximately 15-feet above the top of the confining clay layer. These artesian conditions are supportive of the clay's continuity throughtout the study area.

1.3.4.2 Pump Testing

A series of four 48-hour pump tests were conducted by the NCBW&L in April and early may of 1986. These tests were conducted in an effort to reinstate on-site production well PW-11 as a source of potable water. As a means of addressing the issue of aquifer interconnection, the final pumping test, which was conducted on 29 April through 1 May 1986, was conducted in conjunction with a comprehensive monitoring program. As part of the monitoring program, the water levels in the Upper Potomac observation well (well PH) and eight shallow monitoring wells were recorded for the duration of the 48-hour test (Appendix B). Additionally, the tidal fluctuations in the Delaware River, located approximately one-half mile east of the site, were estimated from published tidal tables and are included as part of the water level hydrographs in Figure 1-5. As this Figure illustrates, fluctuating tidal levels in the Delaware River had no apparent effect on water levels measured in the monitoring wells at the New Castle Spill Site.

Aquifer interconnection, if present, can be identified by two responses to pumping. These are: 1) dropping water levels in the upper Columbia aquifer, and 2) the shape of the data plot generated from the pump test data recorded from the Upper Potomac observation well PH.

The hydrographs for the "OB" series wells, as illustrated in Figure 1-5, do not show a decrease in water level due to pumping. In fact, water levels in these shallow wells show increasing water levels over the duration of the pump test. These rising water levels are attributed to a clogged storm sewer into which purge water was diverted (see Figure 1-3). Subsequent overflow and ponding on the surface resulted in the infiltration and subsequent recharge of the shallow water table aquifer. Recharge to the shallow aquifer was observed approximately 12 hours into the test.

Prior to 12 hours, water levels within the shallow aquifer showed only minimal fluctuations during this time period. For example, although the observed drawdown due to pumping in observation well PH was 16 feet, the water level in well OB-27 fluctuated over a range of 0.1 foot during this time period. Consequently, based on water levels observed in the shallow water table aquifer, no evidence of aquifer interconnection is indicated by pumping the underlying Upper Potomac aquifer.

The data obtained for observation well PH was analyzed by the standard Theis curve matching technique. In this method, a log-log plot of the data is generated. The field data plot is compared to the Theis type-curve drawn to the same scale. Keeping the axis of both plots parallel, the two plots are adjusted until the field data falls on the type-curve. When this match is achieved, an arbitrary match point is selected. The coordinates of this match point (s, t, w(u), 1/u) are used as input into the following equations for determining the transmissivity (T) and storativity (S) of the aquifer being tested:

Transmissivity (T) in gpd/ft:

$$T = \frac{114.6\ QW(u)}{s}$$

Storage Coefficient (S)

dimensionless:

$$S = \frac{Tt}{2693\ (1/u)r^2}$$

Where:

Q = discharge rate (gpm)

r = radial distance to pumping well (feet)

s = determined from match point

t = determined from match point

w(u) = determined from match point

1/u = determined from match point

The data obtained from well PH, located approximately 245 feet northeast of well PW-11, was used to generate the data plot included in Figure 1-6. Over the duration of the 48-hour test, this well showed a total observed drawdown of approximately 20 feet. The shape of the data plot in Figure 1-6 coincides almost precisely with the Theis type-curve and indicates a confined system in which no significant recharge is contributed by leakage from an overlying aquifer. If leakage from any overlying aquifer was apparent, the data plot in Figure 1-6 would show a significant degree of flattening in its mid-section. This flattening is not evident in the data plot generated from the 48-hour test.

The pump test data were used to derive transmissivity and storage coefficient values for the Upper Potomac aquifer. Calculations of these parameters were based on the aforementioned equations and the variables derived from the match point in Figure 1-6. Calculations of these parameters is as follows:

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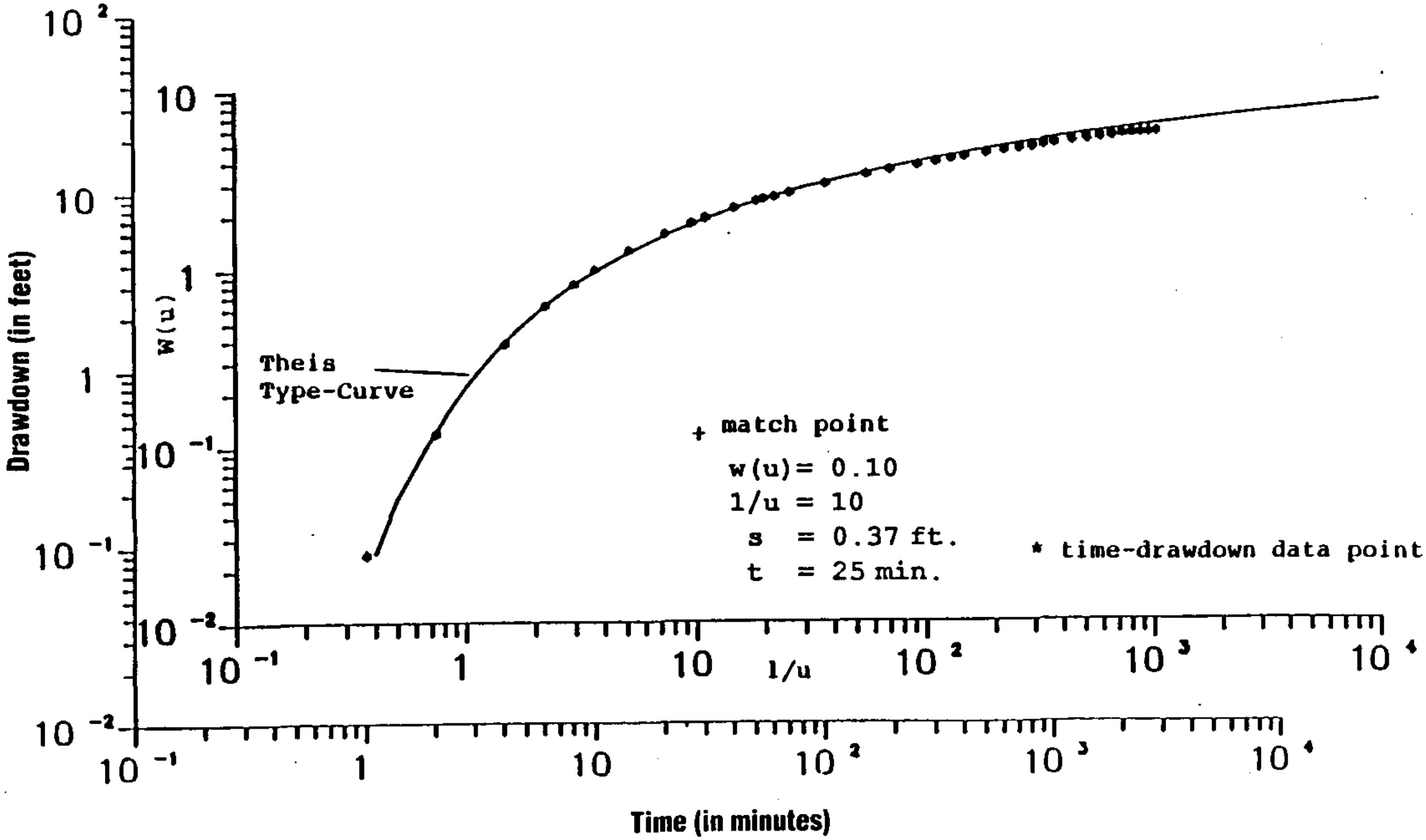
Figure 1-6
Time-Drawdown Plot for Observation Well PH
Pump Test on Well PW-11



$$T = \frac{114.6\ QW(u)}{s} = 6194 \text{ gpd/ft}$$

$$S = \frac{Tt}{2693\ (1/(u)r^2} = 0.00011$$

Where:
$Q = 200$ gpm
$r = 245$ ft.
$s = 0.37$ ft.
$t = 25$ min.
$w(u) = 0.10$
$1/u = 10$

The transmissivity value which was calculated using the Theis method (6194 gpd/ft) is representative of the transmissivity values derived from other pump tests conducted in the region. The calculated value for the storage coefficient (0.00011) is well within the range discussed in Freeze and Cherry (1979) for a confined aquifer.

1.3.4.3 Water Quality Data

A third line of evidence supporting the lack of aquifer interconnection is the historic water quality data for production well PW-11. Since 1978, this well has been sampled nine times for priority pollutant organic compounds. Many of these compounds have consistently been reported as non-detectable. Those compounds detected in one or more monitoring events are included in Table 1-1. Tris analysis was conducted on samples collected in seven of nine sampling events. Of these seven, tris was detected only once, at a trace concentration of 0.03 ug/l in 1980. This trace concentration is considered to be suspect as a result of all other analyses being conducted by various laboratories with a minimum detection limit of 7.0 ppb or greater.

Ground water sampling conducted by BCM in February 1980 identified PCE and TCE at concentrations of 41.1 and 13.6 ug/l respectively. Neither of these two compounds have been detected

TABLE 1-1
Historic Water Quality Data
New Castle Spill Site
Compounds Detected In Production Well No. 11
(all values in ppb)

Date Sampled	Sampler	Tetrachloroethene	Trichloroethene	Tris (Beta-chloropropyl) Phosphate	Bis(2-Ethylhexyl) Phthalate
1/30/79	EPA	<0.2	0.7	0.03	- - -
2/19/80	BCM	41.1	13.6	<7	- - -
3/24/80	BCM	<0.1	<0.1	<9	- - -
4/1/80	BCM	<1	<0.1	<9	- - -
1/18/83	PAS	<1	<1	<10	<10
5/19-20/83	PAS	<1	<1	<20	274
5/19-20/83	E & E	ND	0.6	ND	ND
6/21/84	EPA	- - -	ND	- - -	- - -
4/1-4/86	NCWLC	ND	0.1	- - -	- - -

ND = None Detected, Detection Limit Not Reported
"---" = Not Analysed For

PAS = Princeton AquaScience
E & E = Ecology & Environment
EPA = Environmental Protection Agency
BCM = BCM, Inc (Duffield Associates)
NCWLC = New Castle Water and Light Commision

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at concentrations in excess of 1 ug/l in seven subsequent samplings.

Bis(2-ethylhexyl)phthalate has been identified in three samplings of production well PW-11. Although it was not detected in January 1983, it was identified at a concentration of 274 ug/l in a split sample which was collected in May 1983. The other split of this sample had a concentration reported as non-detectable for this compound. This indicates the probability of a laboratory cross-contamination problem as the source of the 274 ug/l analysis. In addition to sampling of well PW-11, many shallow monitoring wells were also sampled during these three sampling events. Ground water collected from the shallow wells yield non-detectable phthalate concentrations in many of the wells sampled. However, four shallow wells reported phthalate concentrations ranging from 14 to 298 ug/l in at least one sampling.

The elevated levels of bis(2-ethylhexyl)phthalate, in production well PW-11, are not likely to be the result of vertical communication between the shallow Columbia aquifer and Upper Potomac aquifer for two reasons: 1) attenuative processes, and 2) the specific gravity of the phthalate compound.

The single reported concentration of 274 ug/l in production well PW-11 is comparable to the highest concentration reported in the shallow monitoring wells (298 ug/l). It is highly likely, that if this compound were introduced by vertical leakage through the confining clay layer, several attenuation processes such as dilution, adsorption, and chemical decay, would have occurred, significantly reducing the concentration of this phthalate as it passed through the clay and into the Upper Potomac aquifer. Additionally, it is unlikely that these mechanisms would not be present to reduce the concentration of this compound as it migrated through the 80 to 90 feet of clay, sandy clay, sand and gravel that comprises the confining layer. Secondly, the specific gravity of bis(2-ethylhexyl)phthalate is 0.99 gm/cm. Consequently, this compound is considered lighter than water and would not have a tendency to sink. Therefore, the only likely source for the phthalate present in the split sample collected from production well PW-11 would be laboratory cross-contamination. Based on this analysis and the lack of any detectable compounds above trace levels, it is concluded that the ground water produced from production well PW-11 is of good quality and has not been impacted by contamination from the upper aquifer.

1.3.4.4 Vertical Permeability Testing of the Clay

Shelby tube samples of the clay were collected by ERM at five locations during the RI drilling program. Results of the permeability tests ranged from 1.46×10^{-8} cm/sec to 4.83×10^{-8} cm/sec. Subsequent calculations undertaken to determine leakage through the clay suggest a vertical flow rate of 1.7×10^{-5} ft/day (6.3×10^{-3} ft/year), reflecting the nearly impermeable nature of the clay unit. Refer to Section 4.4.2 for a detailed discussion of this data.

1.4 Report Organization

The remainder of the RI Report is divided into chapters, which are briefly outlined below:

Section 2	Environmental Setting - An overview of regional and local geology and hydrology, including aquifer systems and disposal histories.

Section 3	Field Program - The field activities and procedures associated with the monitoring well installation program, aquifer tests, and sampling procedures.
Section 4	Nature and Extent of Contamination - Field sampling results, extent of contamination, and evaluation of contamination.
Section 5	Summary and Conclusions - Conclusions of the study.

Figure 1-5
Water Level Hydrographs
Pump Test of Well PW-11
29 April to 1 May 1986

New Castle Spill Site

(Continued)

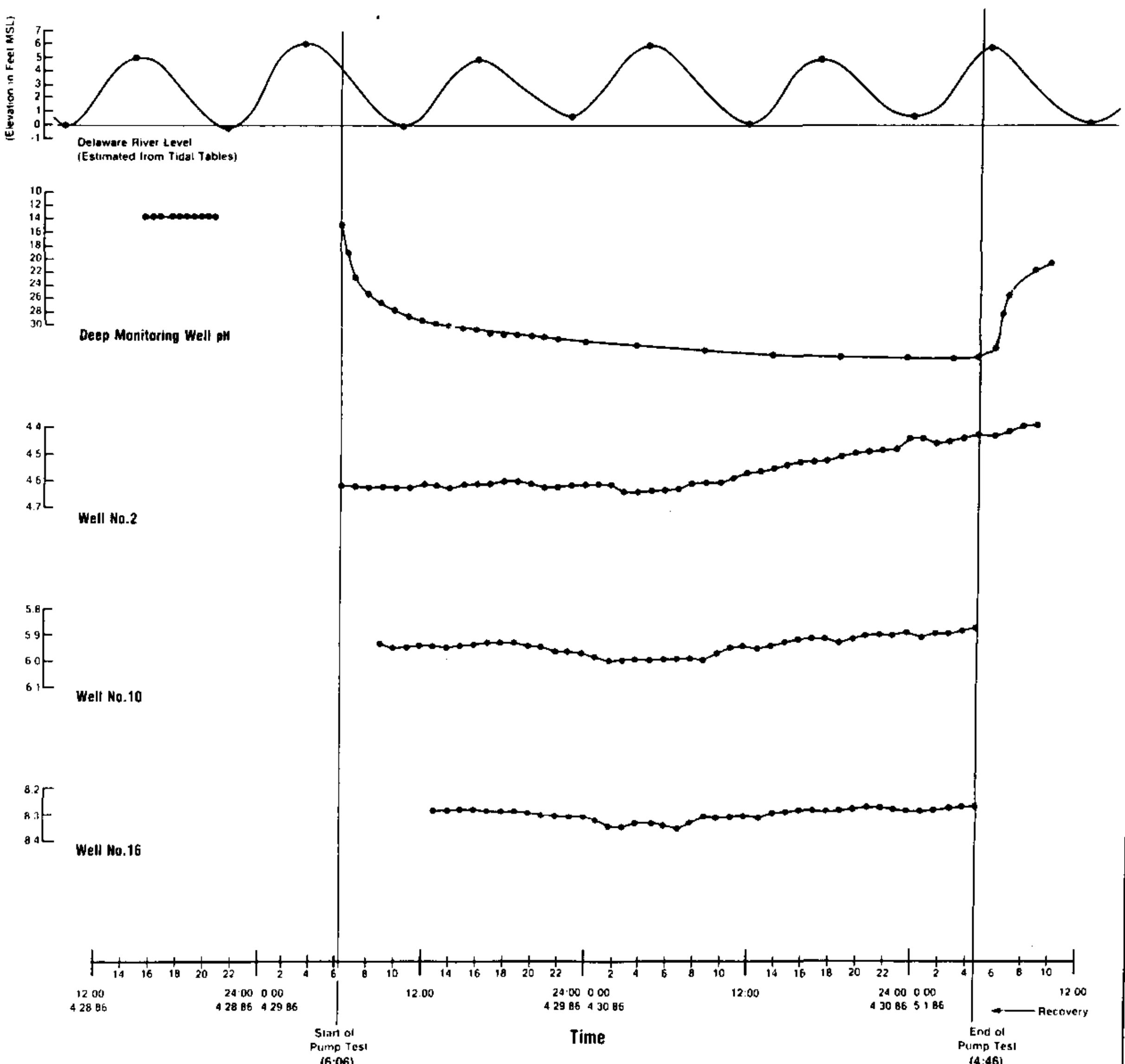

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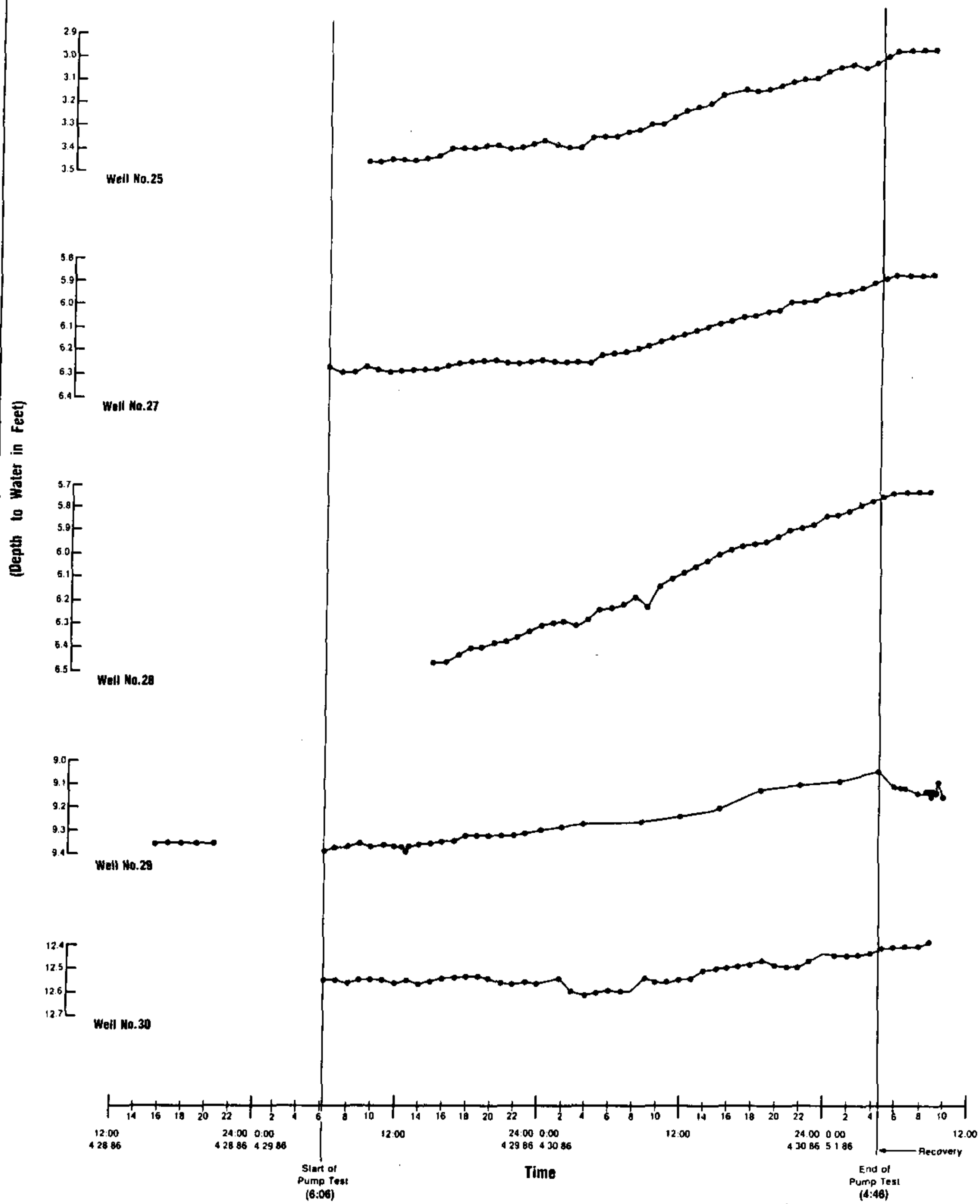
Figure 1-5
Water Level Hydrographs
Pump Test of Well PW-11
29 April to 1 May 1986
New Castle Spill Site



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SECTION 2

ENVIRONMENTAL SETTING

2.1 Physiography

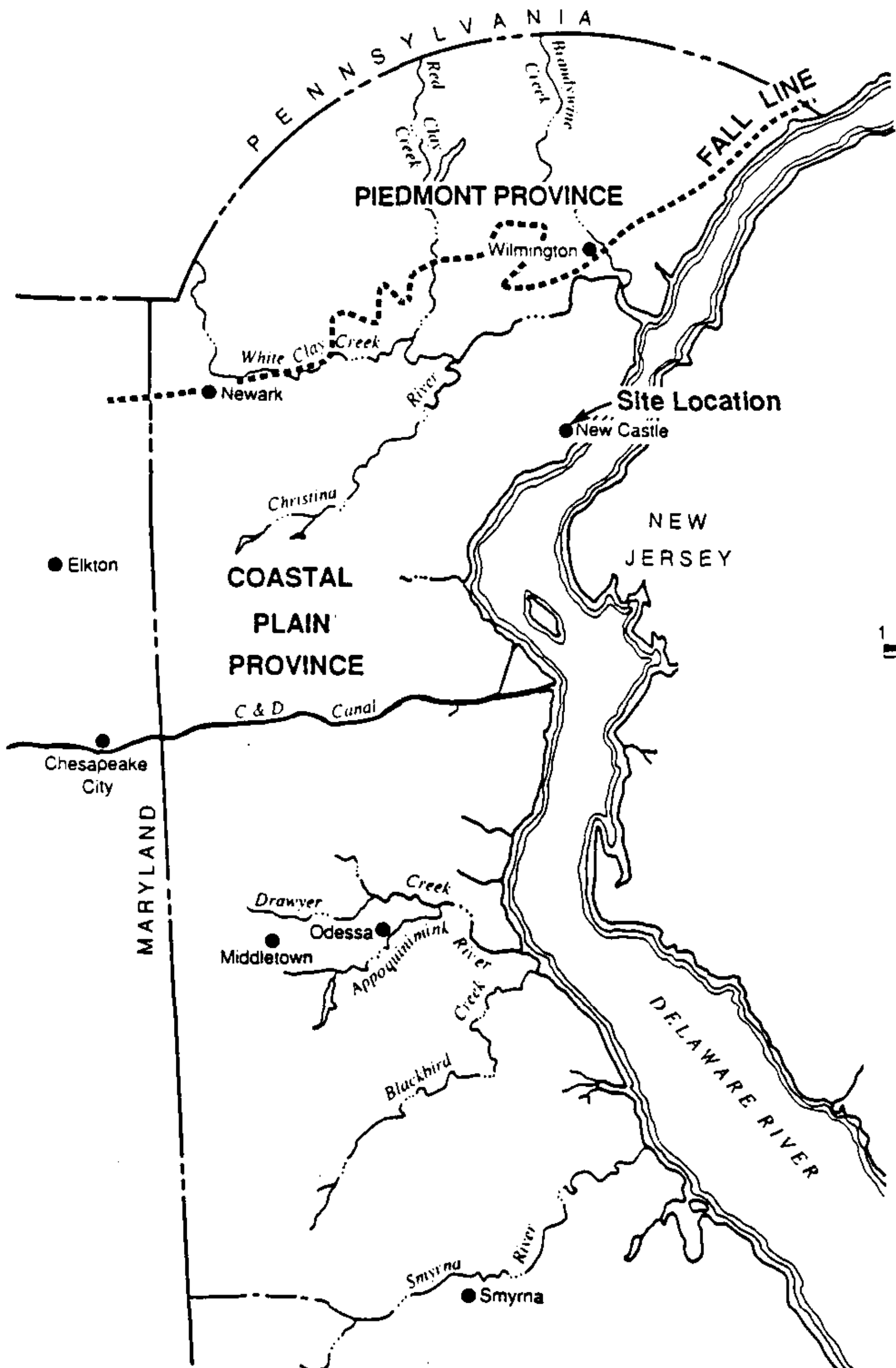
The town of New Castle is located in northern Delaware within the Coastal Plain physiographic province (Figure 2-1). Both the Witco Corporation and the NCBW&L properties are relatively flat lying and are located within the Delaware River flood plain. According to the USGS Wilmington-South, Delaware-New Jersey 7.5 minute quadrangle, elevations within the study area range from 0 to 10 feet above mean sea level. Surface water drainage from the site follows the gently sloping topography to the west-northwest discharging into a swale running along the railroad embankment on the west side of the study area, and then to a marsh, which drains to the south and ultimately to the Delaware River.

2.2 Regional Geology

The study area is underlain by Pleistocene age sands and gravels of the Columbia Formation. In New Castle County, these surficial deposits of the Columbia Formation occur as channel fillings, which form a thickening wedge in a southerly direction. The Columbia reaches a maximum thickness of 150 feet and covers most of the Coastal Plain province in Delaware. Jordan (1964) attributes Columbia deposition to fluvial processes by streams entering Delaware from the northeast and spreading south to southeast across the state.

Unconformably underlying the surficial deposits are the Cretaceous sands and gravels of the Potomac Formation. The

Figure 2-1
Physiographic Province Map
New Castle County, Delaware



Source: Modified From Sundstrom and Pickett, 1971.

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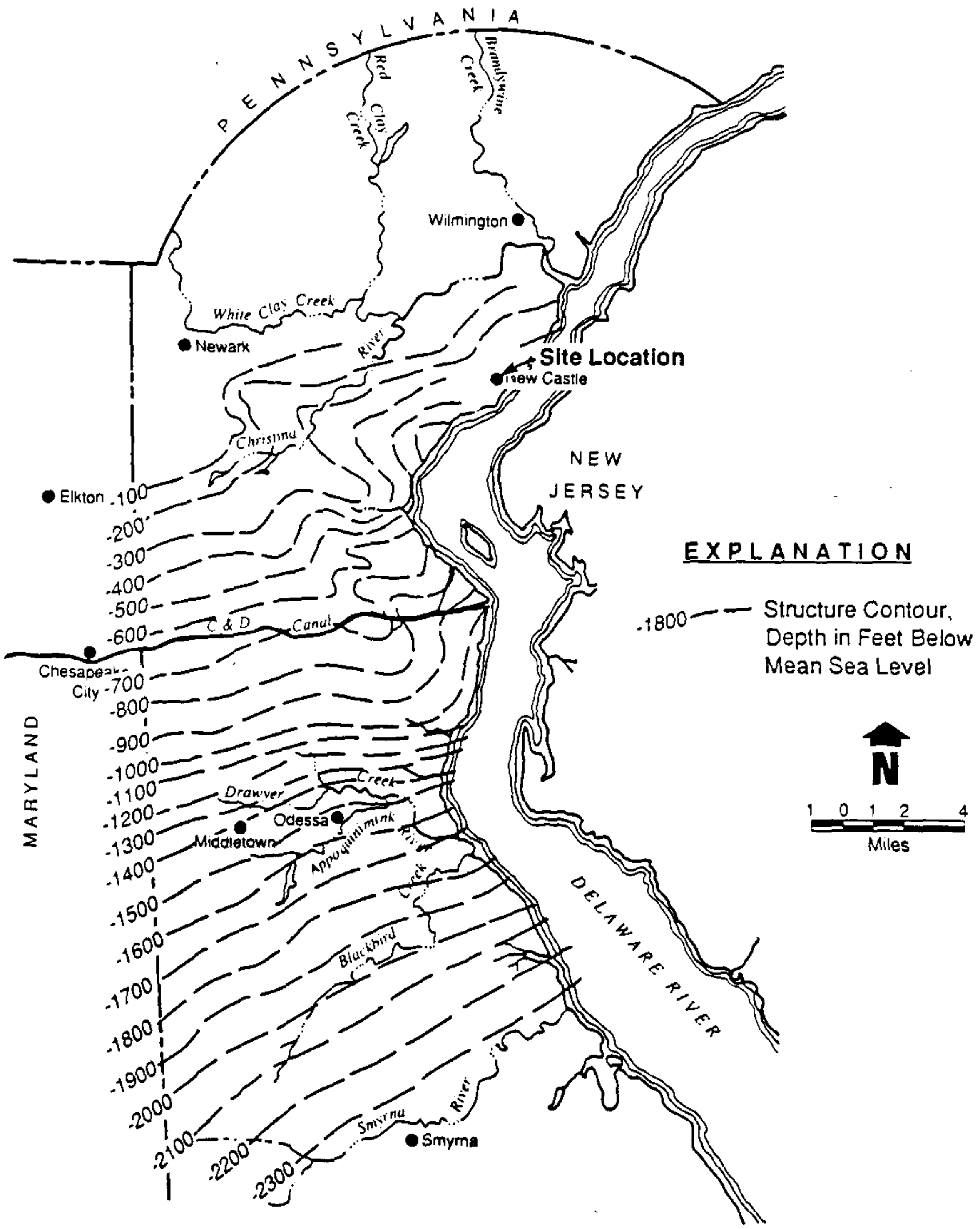
Potomac Formation consists primarily of discontinuous and irregular clays and silts with occasional interbedded sand lenses. These deposits, like those of the Columbia Formation, are attributed to fluvial depositional processes, and thicken to the southeast (Sundstrom and Pickett 1971).

Designating the top of the Potomac Sediments in the vicinity of the area of investigation is a characteristic stiff clay layer. According to the Hydraulic Map Series No. 3, Geohydrology of the Wilmington Area, developed by the Delaware Geological Survey, this clay ranges from 12 to 90 feet in thickness and is present throughout the study area. Figure 2-2 shows the thickness of the clay immediately underlying Columbia Deposits in the vicinity of the New Castle Spill Site.

The crystalline basement rock that unconformably underlies the coastal plain sediments of northern Delaware is classified as the Wissahickon Formation and the Wilmington Complex. The Wissahickon Formation is composed of a biotite-quartz-plagioclase-feldspar-schist which generally strikes to the northeast, while the Wilmington Complex consists of amphibolites, gabbros, banded gneisses and some granites (Sundstrom and Pickett 1971). Within New Castle County, the crystalline basement dips generally to the south-southeast at a rate of approximately 89 feet per mile and has elevations ranging from greater than 100 feet above sea level to approximately 2,300 feet below sea level (Figure 2-3).

Figure 2-4 is a generalized geologic map of New Castle County showing pre-Pleistocene deposits. Table 2-1 gives the stratigraphy present within the county and a general description of each lithologic unit.

Figure 2-3
Structure of the Top of Crystalline Basement Rocks
New Castle County, Delaware



Source: Modified From Sundstrom and Pickett, 1971.

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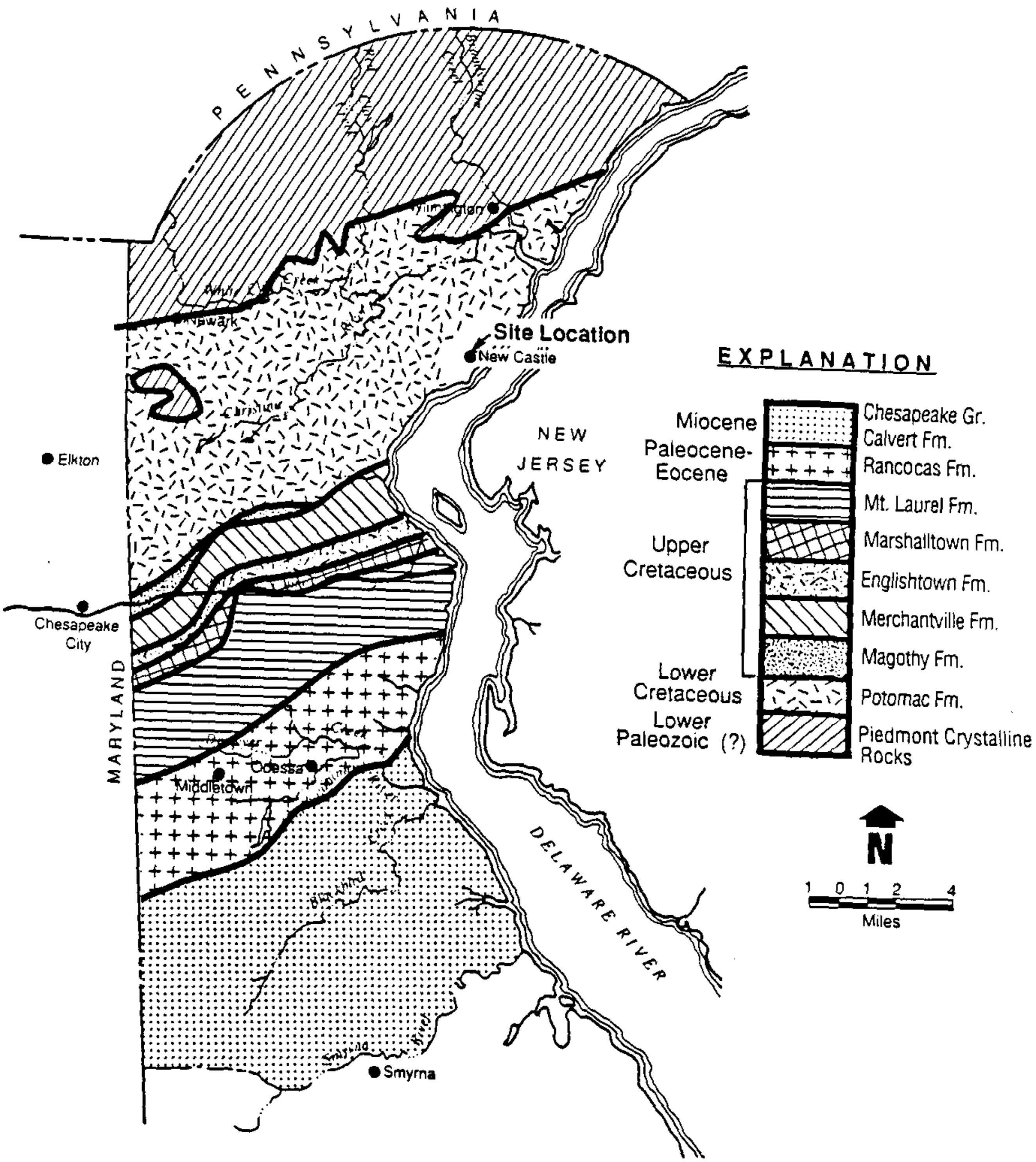
Figure 2-4
Generalized Geologic Map for New Castle County, Delaware



Source: Modified From Sundstrom and Pickett, 1971.

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Table 2-1
Stratigraphic Units Present Within New Castle County

Age	Name	Description	Area of Occurrence
Holocene	Marsh deposits	Silt and Clay	Near Delaware River
Pleistocene	Columbia Formation	Sand and Gravel	Throughout coastal plain
Miocene	Chesapeake Group (Calvert equivalent)	Silt, Clay and some sand	Southern New Castle County
Eocene-Paleocene	Unit C Rancocas Formation	Glauconitic silt and clay Glauconitic sand and silt	Southernmost New Castle County Southern New Castle County
Paleocene-Cretaceous	Unit B	Glauconitic silt and clay	Southern New Castle County
Late Cretaceous	Mount Laurel Formation Marshalltown Formation Englishtown Formation Merchantville Formation Magothy Formation	Glauconitic sand Glauconitic silty fine sand Fine to medium sand Silty fine sand Sand and silt, interbedded	Canal area* and a few miles south Canal area* and a few miles south Canal area* and a few miles south Canal area* and a few miles south Southern New Castle County
Early Cretaceous	Potomac Formation	Variegated clay and sand, interbedded	Throughout Coastal Plain
Lower Paleozoic-Precambrian	Wilmington Complex	Amphibolite, gneiss & gabbro	Northeast New Castle County
	Wissahickon Formation	Schist and Gneiss	Northwest New Castle County
	Cockeysville Formation	Marble	Locally, North of Newark
Unknown	Bryn Mawr Formation	Sand and silt with some gravel	Locally, near Concord Pike and northernmost New Castle County

* Canal area refers to the area near the Chesapeake and Delaware Canal
After Sundstrom and Pickett, 1971

2.3 Regional Hydrogeology

The coastal plain sands and gravels which are present in much of New Castle County can be subdivided into two separate aquifer systems. Columbia deposits of Pleistocene age serve as the upper system or water table aquifer. The lower Potomac system is more varied and contains several discontinuous confined sand lenses which may serve as good water producers.

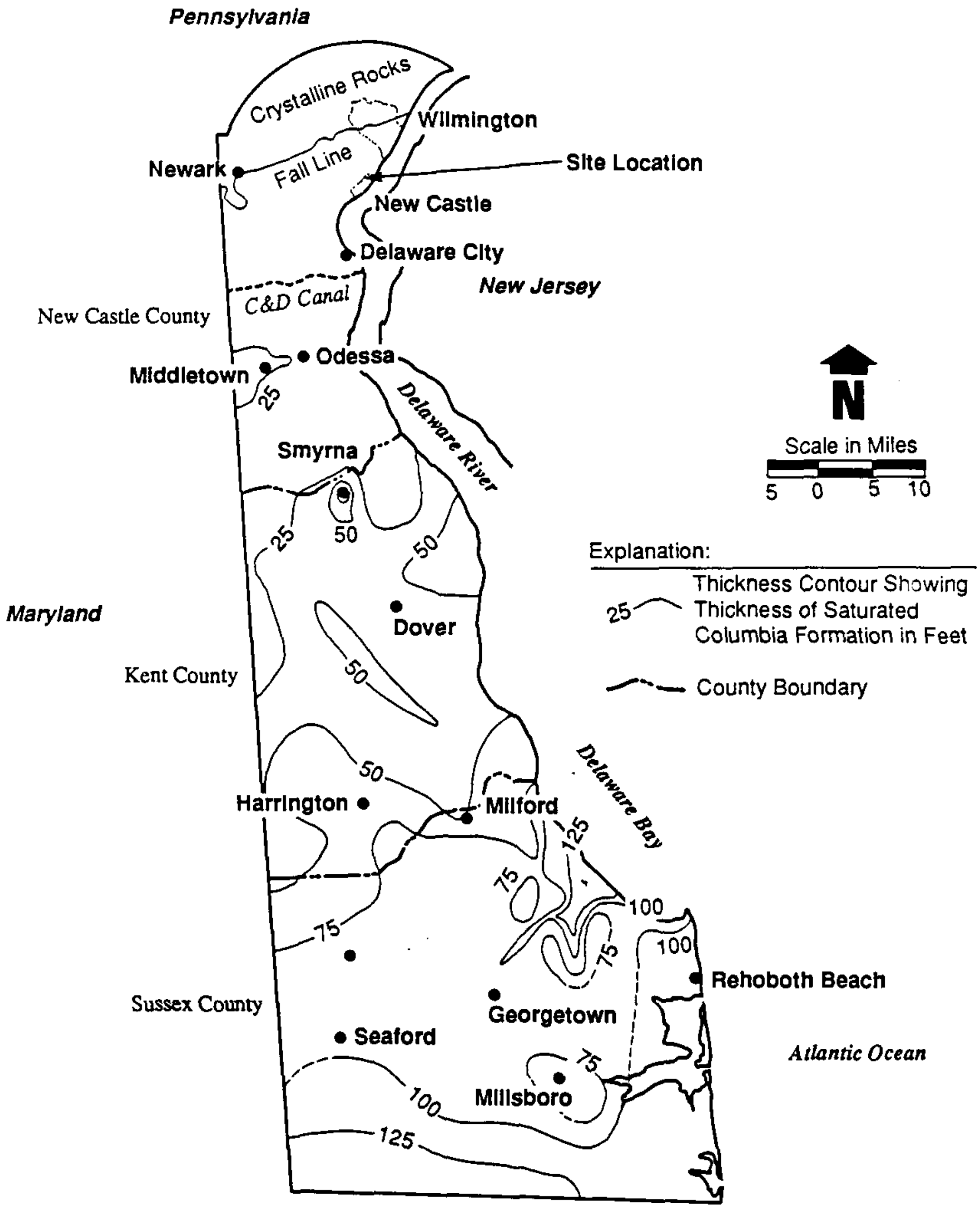
2.3.1 Columbia Aquifer

The Columbia aquifer, recognized as the water table aquifer, covers approximately 1,500 square miles within the State of Delaware. These deposits have a saturated thickness ranging from a few feet in New Castle County to approximately 150 feet in southwest Sussex County (Figure 2-5). Within New Castle County, 5 percent (21 mi^2) of land area is underlain by saturated Columbia deposits of at least 25 feet in thickness.

Ground water recharge occurs primarily during months between October and April when ground water demand is low. During high demand months, May through September, occasional heavy rains can provide sufficient volumes of water to satisfy soil moisture requirements, allowing the surplus to infiltrate and recharge the water table. The total recharge to the Columbia deposits within the entire 1,500 square mile surface area in Delaware is estimated to be approximately 1 billion gallons per day (Johnston 1973).

The Columbia deposits continually discharge baseflow to non-tidal streams that drain the coastal plain deposits of Delaware. Additionally, Columbia deposits discharge ground water to both the Delaware Bay and Atlantic Ocean. Approximately 72 percent of total stream flow is attributed to baseflow contributed by ground

Figure 2-5
Isopach Map of the Saturated Columbia Formation in Delaware



Source: Modified from Johnson, 1973

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water. The total ground water discharge through these streams is estimated at approximately 800 million gallons per day. Other sources of ground water discharge are transpiration through vegetation and ground water withdrawals for industrial and domestic purposes.

Several aquifer pumping tests have been conducted in an effort to determine the hydraulic characteristics of the Columbia aquifer at various localities across the state. Each test was unique with respect to pumping rate and duration of pumpage, the lithologies encountered, and the saturated thickness of the materials being tested. Within the Columbia aquifer, hydraulic conductivities range from 15 ft/day to 250 ft/day (0.005 cm/sec to 0.09 cm/sec). Transmissivities within the Columbia range from 9,000 gal/day/ft to 165,000 gal/day/ft (12.94 cm^2/sec to 237.27 cm^2/sec). Storage coefficients range from 0.01 to 0.07.

Ground water contained within the Columbia aquifer is generally classified as soft and slightly acidic, and typically has a low dissolved solid content. The primary dissolved constituents within the ground water are calcium, sodium, potassium, silica, bicarbonate, sulfate, chloride and nitrate (Johnston 1973). Additionally, ground water derived from the Columbia aquifer typically exceeds the secondary drinking water standard of 0.3 ppm for iron. Table 2-2 gives the typical concentrations of inorganic constituents found in 19 wells completed in the Columbia aquifer at various locations across Delaware.

2.3.2 Potomac Formation

The Potomac Formation immediately underlies the Columbia deposits in the northern coastal plain of Delaware. Beneath the Columbia, the three subunits of the Potomac have a sub-crop area of approximately 100 square miles. Potomac sediments form a wedge

Table 2-2
Typical Concentrations of Inorganic Constituents in the Columbia Aquifer, Delaware

Constituent	Concentration (ppm)		
	Minimum	Maximum	Average
Silica (SiO_2)	9.8	25	16
Iron (Fe)	0	2.1	0.33
Calcium (Ca)	1.6	17	7.6
Magnesium (Mg)	0.4	13	5.2
Sodium and Potassium (Na+K)	3.7	40	15
Bicarbonate (HCO_3)	4	38	17
Sulfate (SO_4)	0.4	40	13
Chloride(Cl)	4	86	21
Nitrate (NO_3)	0	36	13
Dissolved Solids	50	235	113
Hardness (as $CaCO_3$) :			
Calcium, Magnesium	5	93	39
Noncarbonate	0	64	18
pH	5.4	7.5	6.1

(After Johnston,1973)

which thickens to the southeast. In the southeastern portion of New Castle County, these sediments are over 1,700 feet thick (Figure 2-6).

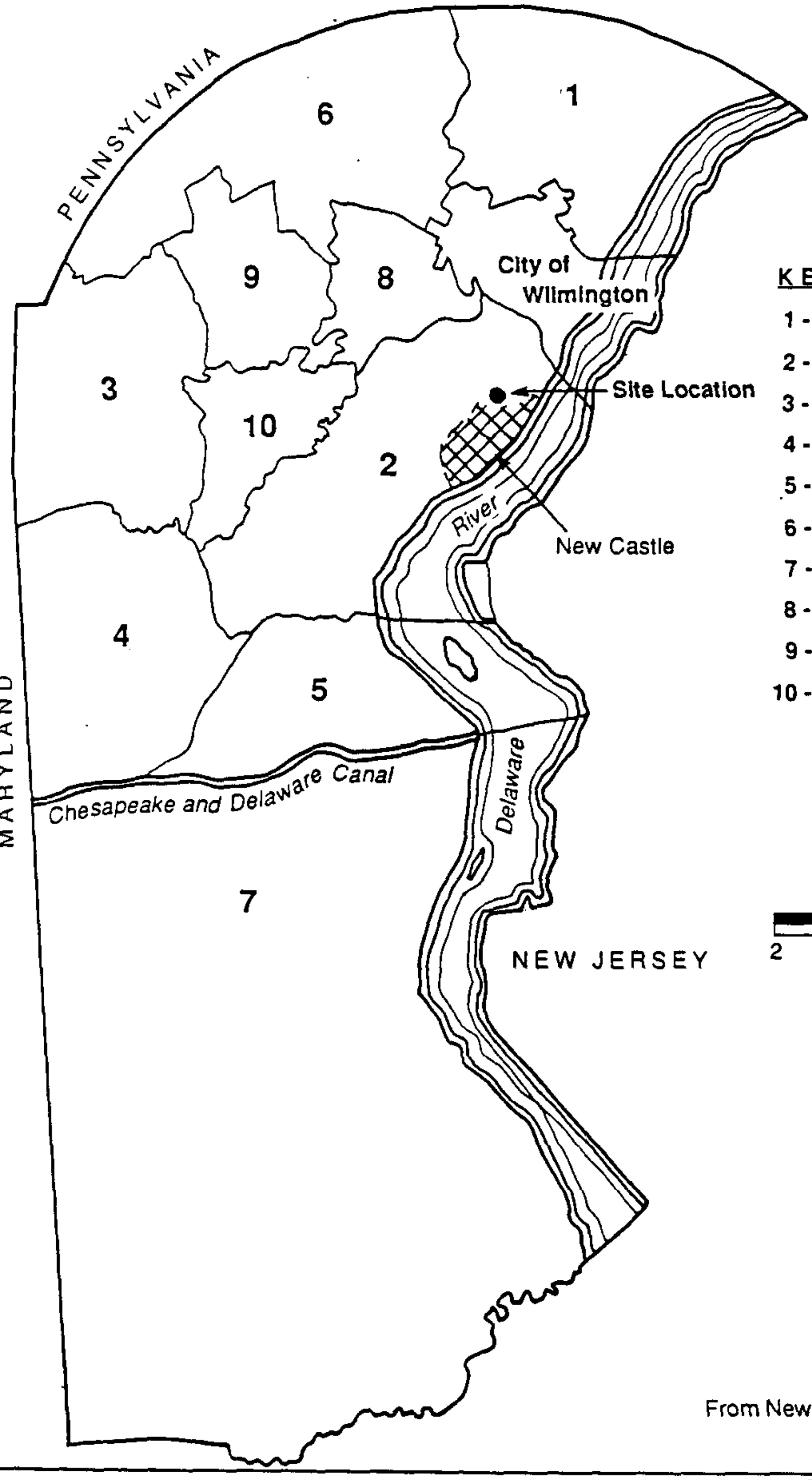
On a regional scale, the ground water of the water table aquifer is considered a possible source of recharge to the underlying Potomac aquifer. However, locally the sands of the Potomac aquifer are mantled by a clay unit which is continuous in the vicinity of the New Castle Spill Site. This clay unit isolates the Columbia and Potomac Systems as evidenced by permeability testing of clay samples obtained from within the study area. Additionally, the pump testing conducted in 1986 supports a lack of aquifer interconnection between the shallow Columbia aquifer and deep Potomac aquifer systems at the site (refer to section 1.3.4).

Discharge from the Potomac aquifer system is primarily through pumpage for both industrial and municipal purposes. Additional ground water is discharged to streams in the northern portions of the sub-crop areas.

Several aquifer pumping tests have been conducted within New Castle County to determine the aquifer characteristics of the Potomac system. Each pumping test was unique with respect to the pumping rate, duration of pumpage and lithologies tested. Transmissivities within the Potomac range from 3,405 gal/day/ft to 63,601 gal/day/ft (4.89 cm^2/sec to 1.46 cm^2/sec). Storage coefficients range from 9.6×10^{-5} to 1.5×10^{-3} (Martin 1982). Table 2-3 gives selected results from several aquifer tests conducted within New Castle County.

Analytical results of samples collected from the Potomac aquifers at several locations within New Castle County indicate that the dissolved solids in the waters derived from the Potomac

Figure 2-7
Location of the Ten Planning Districts in New Castle County, Delaware



KEY - Planning Districts

1 - Brandywine
2 - New Castle
3 - Greater Newark
4 - Central Pencader
5 - Red Lion
6 - Piedmont
7 - Middletown-Odessa-Townsend
8 - Lower Christina
9 - Pike Creek-Central Kirkwood
10 - Upper Christina

From New Castle County, 1987

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TABLE 2-3
Selected Results From Aquifer Tests Conducted On Potomac Sediments
New Castle County, Delaware

LOCATION	TEST DURATION	PUMPING RATE	TRANSMISSIVITY gal/day/ft.	COEFFICIENT OF STORAGE
Airport Industrial Park	7Hrs	300 GPM	5070	0.00016
Army Creek Landfill	30Hrs	525 GPM	26925	0.0015
Delmarva Power Summit	47Hrs	250 GPM	4950	0.000096
Glendale	45Hrs	524 GPM	6840	0.0025
Goodrich	48Hrs	200 GPM	38100	0.0001
New Castle	96Hrs	420 GPM	58876	0.00045
New Castle	24Hrs	207 GPM	22050	0.0002
New Castle	9.2 Days	376 GPM	7650	0.0023
New Castle	48Hrs	305 GPM	7455	0.00014
Ommelanden Park	8.5Hrs	343 GPM	63601	0.00023
Union Carbide	51Hrs	300 GPM	27075	0.0004

(from Martin & Denver, 1982)

consist primarily of iron, sodium, calcium, chloride, sulfate and pH values range from 5.4 to 8.0. Table 2-4 gives the chemical analyses of selected samples collected from the Potomac System within New Castle County.

2.4 Demography

Growth patterns within the County of New Castle have followed trends similar to those observed within other areas of the northeast corridor. Since 1970, population trends have shown a 12 percent decrease in population within the City of Wilmington, and a 16.6 percent growth rate within the rest of the county. Since 1980, the average annual rate of population growth within the county has increased to 4,030 persons per year, as compared to 2,245 persons per year between 1970 and 1980. Along with an increased growth in population, population density within the county has increased from the 1970 estimate of 730 persons per square mile to 851 persons per square mile in 1987. A comparison of census data from 1970 and 1980 indicates a general aging trend within the county, and projections suggest that this aging trend will continue.

Population projections from 1985 through 2010 show an anticipated 24.9 percent population increase within the county by the year 2010. Population growth is attributed to two primary factors:

- The expansion of the greater Philadelphia area

- The large number of babies being born to the baby boom generation

Employment within New Castle County is primarily by the manufacturing, trade and service industries.

TABLE 2-4
Typical Concentrations of Inorganic Constituents
in the Potomac Formation
New Castle County, Delaware

Constituent	Range	
	Minimum	Maximum
Silica (SiO_2)	0	11
Iron (Fe)	0	42
Calcium (Ca)	1.42	139
Magnesium (Mg)	1	16
Sodium (Na)	0	136
Bicarbonate (HCO_3)	0	189
Sulfate (SO_4)	0	141
Chloride(Cl)	0	515
Hardness (Non-Carbonate)	0	157
Hardness ($CaCO_3$)	0	245
pH	5.4	8

(from Martin & Denver 1982)

The New Castle Spill Site, and the City of New Castle, are located within the New Castle planning district (Figure 2-7). The New Castle planning district is the third most populated district within New Castle County. The New Castle area has shown an 18.1 percent increase in population growth since 1970. Much of the growth, development and subsequent employment opportunities within the district may be a direct result of the location of major highways, such as I-95, I-495, I-295, US Route 13, US Route 301, US Route 40 and Delaware Route 273. Both I-95 and I-495 provide interstate access to Pennsylvania and Maryland, while I-295 provides access via the Delaware Memorial Bridge to New Jersey. Additionally, the location of rail lines and the Greater Wilmington/New Castle County airport has provided several opportunities for economic development.

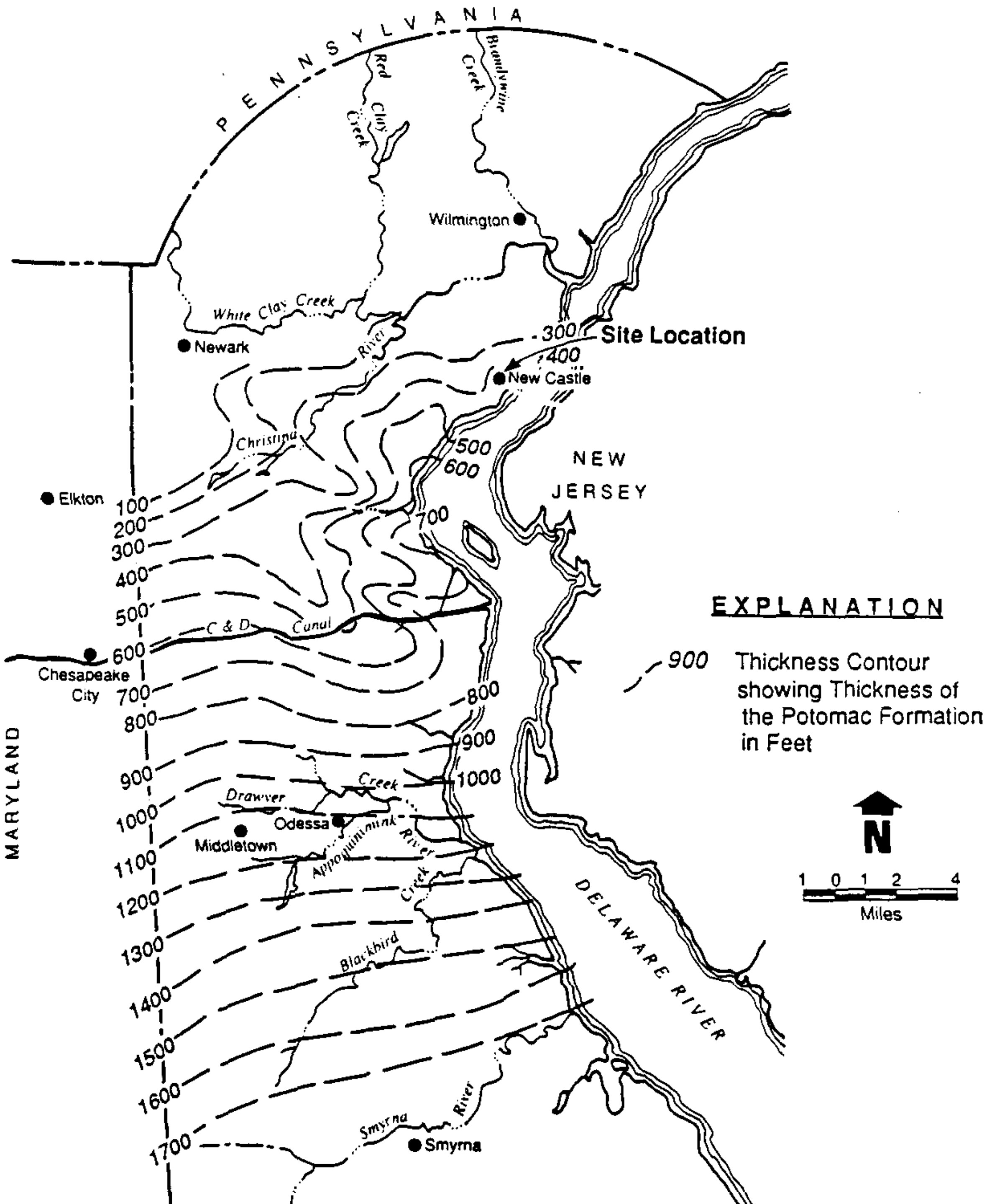
2.5 Land Use

Within New Castle County, the northern one-third, including the Greater Wilmington area and its associated suburbs, is urbanized. The City of New Castle falls within this land use pattern. Large tracts of undeveloped land remain south of US Route 40 and Route 273 and sit as open field or swampy areas or are used for agricultural purposes.

2.6 Climatology

The climate of New Castle County is typically warm and humid in the summer, and moderately cold in the winter. Annually, the average temperature ranges from a January low of 31.2°F, to a July high of 76°F. Average minimum and maximum temperatures during the period from 1951 to 1980, as recorded at the National Weather Service (NWS) station at Wilmington, Delaware (the closest NOAA weather station) are presented in Table 2-5.

Figure 2-6
Isopach Map of the Potomic Formation Within New Castle County Delaware
New Castle County, Delaware



Source: Modified From Martin and Denver, 1982.

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Table 2-5
Mean Monthly Precipitation and Temperature Data at the
National Weather Service Station
Wilmington, Delaware

Month	Mean Precipitation (inches)	Mean Temperature (Farenheit)
January	3.11	31.2
February	2.99	33.2
March	3.87	41.8
April	3.39	52.4
May	3.23	62.2
June	3.51	71.2
July	3.9	76
August	4.03	74.8
September	3.59	67.9
October	2.89	56.3
November	3.33	45.6
December	3.54	35.5

* Monthly means are determined from climatological data from 1951 thru 1980.

SOURCE: National Oceanic and Atmospheric Administration

The average annual precipitation for New Castle County, including both rainfall and the water equivalent of melting snow, is 41.38 inches. Precipitation normals during the period 1951 to 1980, as recorded at the NWS station at Wilmington are presented in Table 2-5.

Variations in temperature and precipitation do occur depending on location within the county. For example, of the four weather stations located within New Castle County, the weather station at Wilmington's Porter Reservoir exhibits the lowest average temperature, as well as the highest amount of precipitation (53.3°F and 44.9 inches, respectively). The most likely explanation for these differences may be the higher elevation (274 feet above sea level) of the Porter Reservoir Station as compared to the other weather stations, all of which are at elevations less than 100 feet above sea level.

SECTION 3

FIELD PROGRAM

3.1 Well Survey and Tidal Study

Previous investigations of the study area have reportedly resulted in the installation of 24 monitoring wells (Figure 3-1). ERM conducted a well survey to identify which existing wells were functional and to measure total depths of each well (Table 3-1). Wells OB-26 and OB-23 could not be located, and wells OB-22 and OB-17 were vandalized and filled with rocks. The Pump House (PH) well and well OB-1 were the only wells installed with a stick-up, and protective steel riser pipe was installed only on well OB-1. All other wells were constructed of PVC and protected by curb boxes installed flush with the land surface.

Before ERM installed any additional wells, water levels were measured in existing wells to establish the effect of tidal fluctuations on the direction and gradient of ground water flow. Water level measurements were recorded over a 24-hour period in all wells identified by the well survey. Hermit® field data loggers were used in four of the wells, and the remaining wells were measured hourly by hand using an electronic water level indicator. Results of the tidal study were used to select locations of the new monitoring wells.

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Figure 3-1
Existing Monitoring Well Locations
New Castle Spill Site

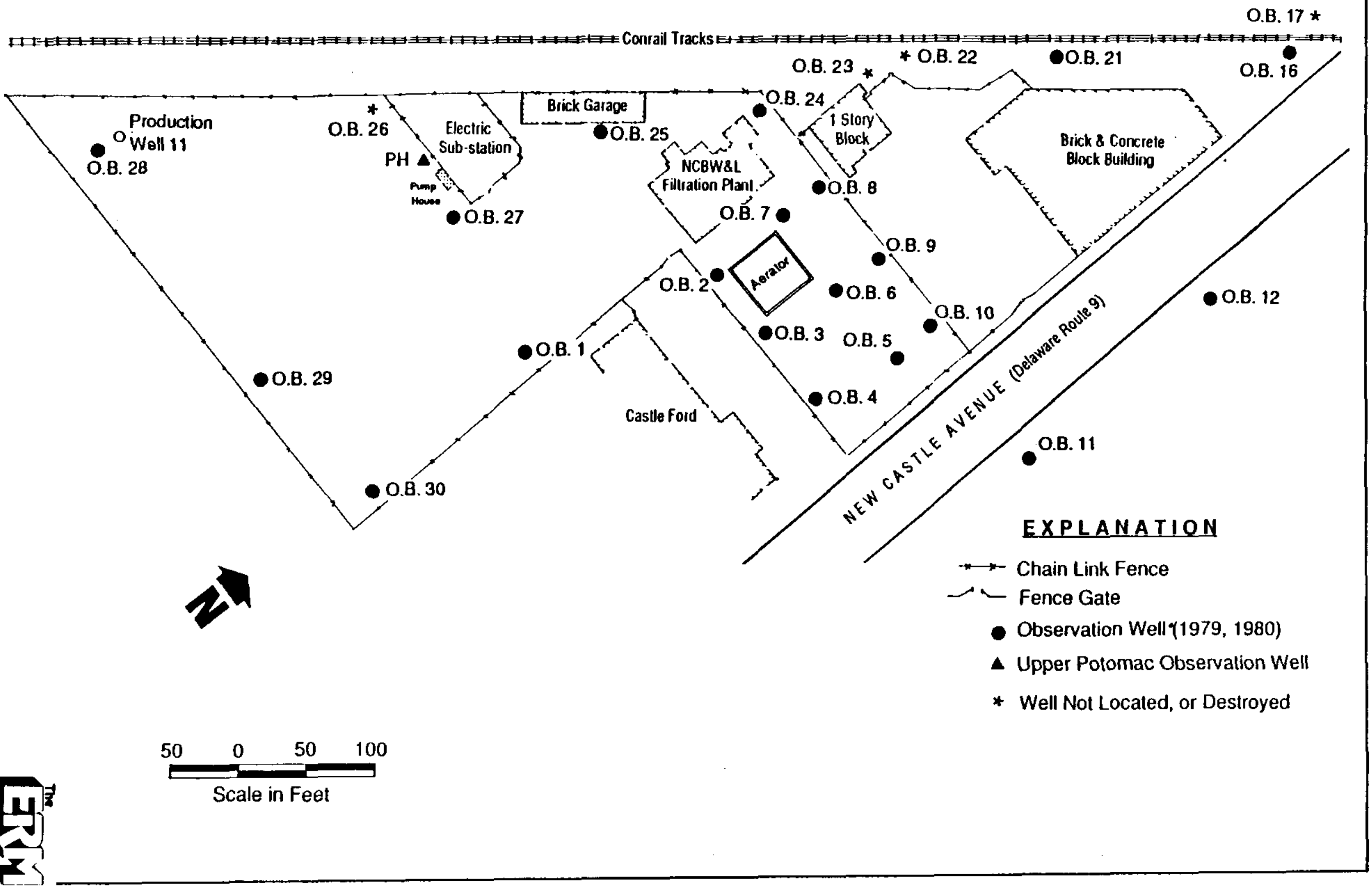

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Table 3-1
Well Construction Details for Monitoring Wells
New Castle Spill Site

Well #	Elevation (feet msl)			Depth Below Land Surface (feet)		Remarks
	Top of Casing	Ground Surface	Screened Interval	Total Depth	Screened Interval	
MW-1	10.57	8.6	-17.4 to -22.4	38	26.0 to 31.0	
MW-2	7.89	5.8	-17.2 to -22.2	45.5	23.0 to 28.0	
MW-3	9.09	7.1	-15.9 to -20.9	35.5	23.0 to 28.0	
MW-4	10.51	8.4	-20.6 to -25.6	41.5	29.0 to 34.0	
MW-5	11.19	9.1	-17.9 to -22.9	39.5	27.5 to 32.5	
PW-1	8.89	7.1	-2.9 to -13.9	32	10.0 to 21.0	
OB-1	9.8	8.7	? to -15.9	24.59	? to 24.59	
OB-2	6.22	6.4	-0.9 to -5.9	12.3	7.3 to 12.3	
OB-3	6.99	7.2	0.2 to -4.8	12.01	7.01 to 12.01	
OB-4	7.56	7.8	0.6 to -4.4	12.19	7.19 to 12.19	
OB-5	8.39	8.6	1.5 to -3.5	12.07	7.07 to 12.07	
OB-6	7.77	8	1.0 to -4.0	12.03	7.03 to 12.03	
OB-7	6.74	7	0.8 to -4.2	11.24	6.24 to 11.24	
OB-8	5.58	5.9	-0.6 to -5.6	11.45	6.45 to 11.45	
OB-9	7	7.1	-0.9 to -5.9	12.97	7.97 to 12.97	
OB-10	7.44	7.7	0.5 to -4.5	12.21	7.21 to 12.21	
OB-11	9.3	9.5	1.8 to -3.2	12.7	7.70 to 12.70	
OB-12	9.9	9.9	1.9 to -3.1	13	8.00 to 13.00	
OB-16	9.26	9.4	2.1 to -2.9	12.3	7.3 to 12.3	
OB-17						Destroyed
OB-21	8.28	8.5	-1.3 to -6.3	14.76	9.76 to 14.76	
OB-22						Destroyed
OB-23						Could not Locate
OB-24	5.54	5.7	-4.0 to -9.0	14.65	9.65 to 14.65	
OB-25	5.16	5.2	-2.9 to -7.9	13.12	8.12 to 13.12	
OB-26						Could not Locate
OB-27	8	8.2	-5.3 to -10.3	18.45	13.45 to 18.45	
OB-28	8.28	8.5	-2.7 to -7.7	16.2	11.2 to 16.2	
OB-29	11.13	11.2	-1.4 to -6.4	17.57	12.57 to 17.57	
OB-30	14.33	14.5	-1.6 to -6.6	21.14	16.14 to 21.14	
PH	9.14	7.2		>100	> 100	
PW-11				141	128 to 141	Production Well

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3.2 Soil Borings

Drilling activities were initiated on 7 March 1988 by Walton Corporation of Newark, Delaware. ERM personnel were on site to supervise the drilling activities. Drilling logs are presented in Appendix C.

The first step in the drilling program was to advance eight soil borings to the top of the water table (Figure 3-2). Six of the eight borings were advanced using hollow stem augers and continuous split-spoon sampling. Borings B-2 and B-3, located adjacent to the Conrail tracks, were advanced by a hand-driven bucket auger because the water table was anticipated to be within 2 to 4 feet of land surface.

The split spoon samples were logged by an experienced hydrogeologist and then divided into two aliquots. One aliquot was treated as a sample and placed into laboratory supplied bottles and handled as described in the QAPP. Approximately 4 ounces from the second aliquot was placed in a bottle for a headspace measurement. Before the headspace measurement was taken, the bottle was placed in a heated room for 1 hour before an Organic Vapor Analyzer (OVA) was used to measure the Volatile Organic Compound (VOC) content.

The headspace measurements (Table 3-2) and visual observations were used to select samples for laboratory analysis. A total of 15 soil samples were submitted to the laboratory from the 8 borings. A minimum of one sample from each boring was tested.

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Figure 3-2
Proposed Soil Boring Locations
New Castle Spill Site

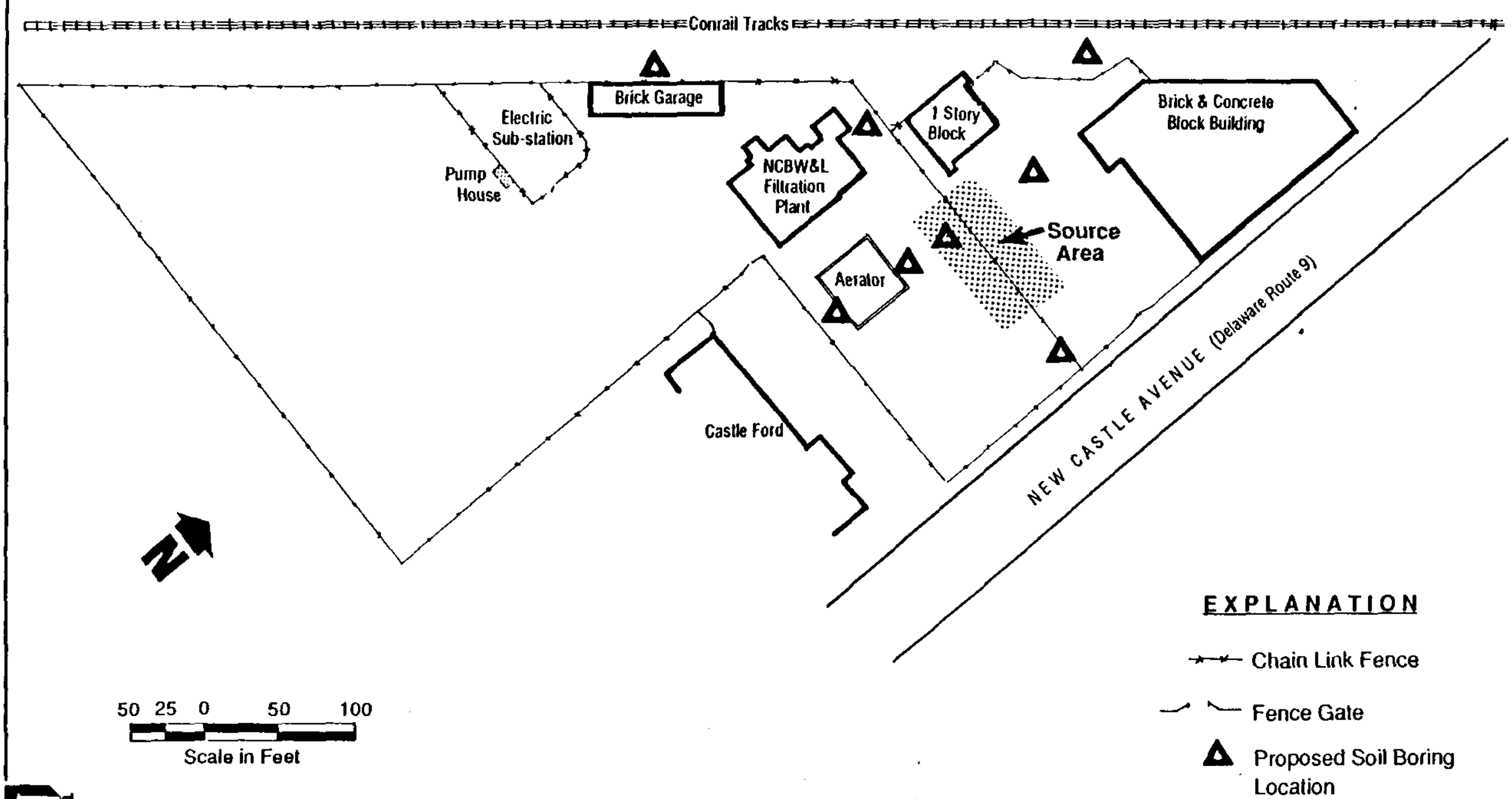

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TABLE 3-2
Headspace Measurements of Split Spoon Samples
New Castle Spill Site

Boring/Well Number	Depth Interval	O.V.A. Reading (ppm)	Boring/Well Number	Depth Interval	O.V.A. Reading (ppm)
B - 1	0 - 2'	0.20	MW - 3	0 - 2'	0.00
	2' - 4'	0.20		2' - 4'	0.30
	4' - 6'	0.40		4' - 6' *	0.10
	6' - 8' *	0.80		6' - 8'	0.80
B - 2	0 - 2'	5.00	MW - 4	0 - 2'	0.00
	2' - 4' *	11.00		2' - 4' *	0.00
	4' - 6' *	12.00		4' - 6'	0.00
				6' - 8' *	0.00
				8' - 10'	0.00
B - 3	0 - 2' *	10.00			
			MW - 5	0 - 2'	1.10
MW - 1	0 - 2' *	0.20		2' - 4' *	12.00
	2' - 4' *	0.30		4' - 6' *	10.00
	4' - 6'	0.00		6' - 8' *	3.70
	6' - 8'	0.20		8' - 10'	3.10
MW - 2	0 - 2'	0.15	PW - 1	0 - 2' *	0.00
	2' - 4' *	0.50		2' - 4' *	0.00
	4' - 6'	0.10		4' - 6'	0.00
				6' - 8'	0.10

* Identifies samples submitted for laboratory analysis

3.3 Ground Water Monitoring

Five new monitoring wells were installed within the study area using auger drilling methods (Figure 3-3). Wells MW-1 through MW-4 were paired with existing wells to create four well nests. Except for well MW-4, the new wells were installed in boreholes originally proposed and drilled as soil borings. When soil borings were completed as monitoring wells, split spoon samples were collected at 5-foot intervals below the water table until the borings contacted the clay unit separating the Columbia and Potomac aquifers. Although well MW-4 was not originally proposed to be a soil boring, the sampling intervals were the same as those for the converted soil borings. Shelby tube samples were obtained 5 feet below the clay surface in each of the five monitoring wells. These samples were collected to investigate the potential for hydraulic communication between the Columbia and Potomac aquifers. Once the Shelby tube sample was collected from the borehole, bentonite pellets were used to backfill the hole to the top of the clay unit. Well construction details including screened interval and total depth for wells installed by ERM are also presented in Table 3-1.

Monitoring wells were constructed of threaded, flush joint, 2-inch ID schedule 40 PVC well casing with factory slotted PVC screen. The screen slot size was 0.02 inch with 20 slots per inch of screen. The wells were screened for an interval of five feet from the top of the clay unit up. The sand pack consisted of Number 1 sand and extended two to three feet above the top of the well screen. After confirming the depth of the sand pack by direct measurement, bentonite pellets were added down the annulus to provide a seal at least two feet thick above the sand pack. Once the seal was in place, a cement/bentonite slurry was tremied through the annulus to fill the void between the top of the bentonite seal and the ground surface. To

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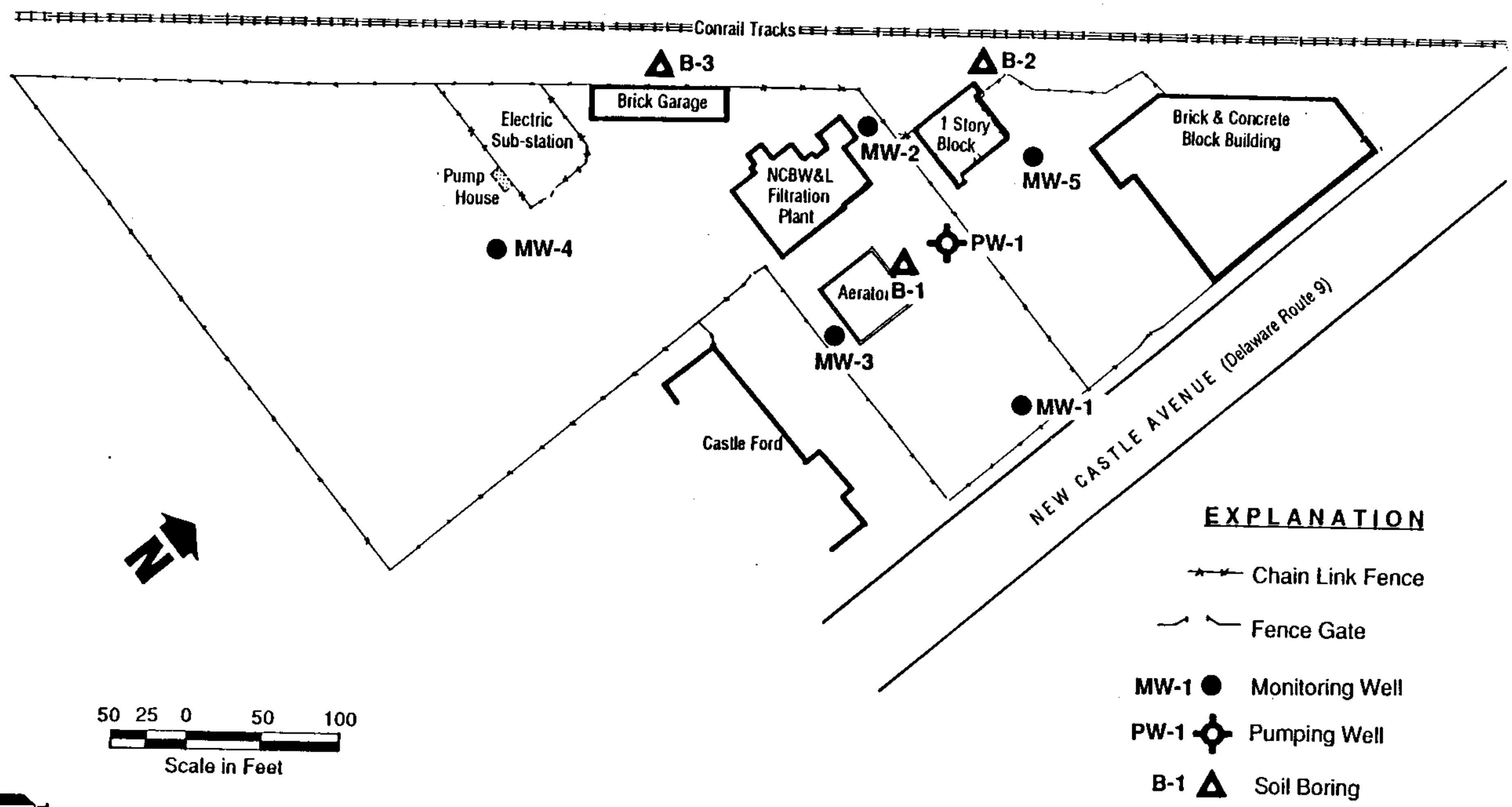
Figure 3-3
Locations of Monitoring Wells and Soil Borings Installed During the Remedial Investigation
New Castle Spill Site



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complete each well construction, a 4-inch inside diameter protective steel casing and locking cap were grouted in place. A typical "as built" diagram for these wells is provided in Figure 3-4.

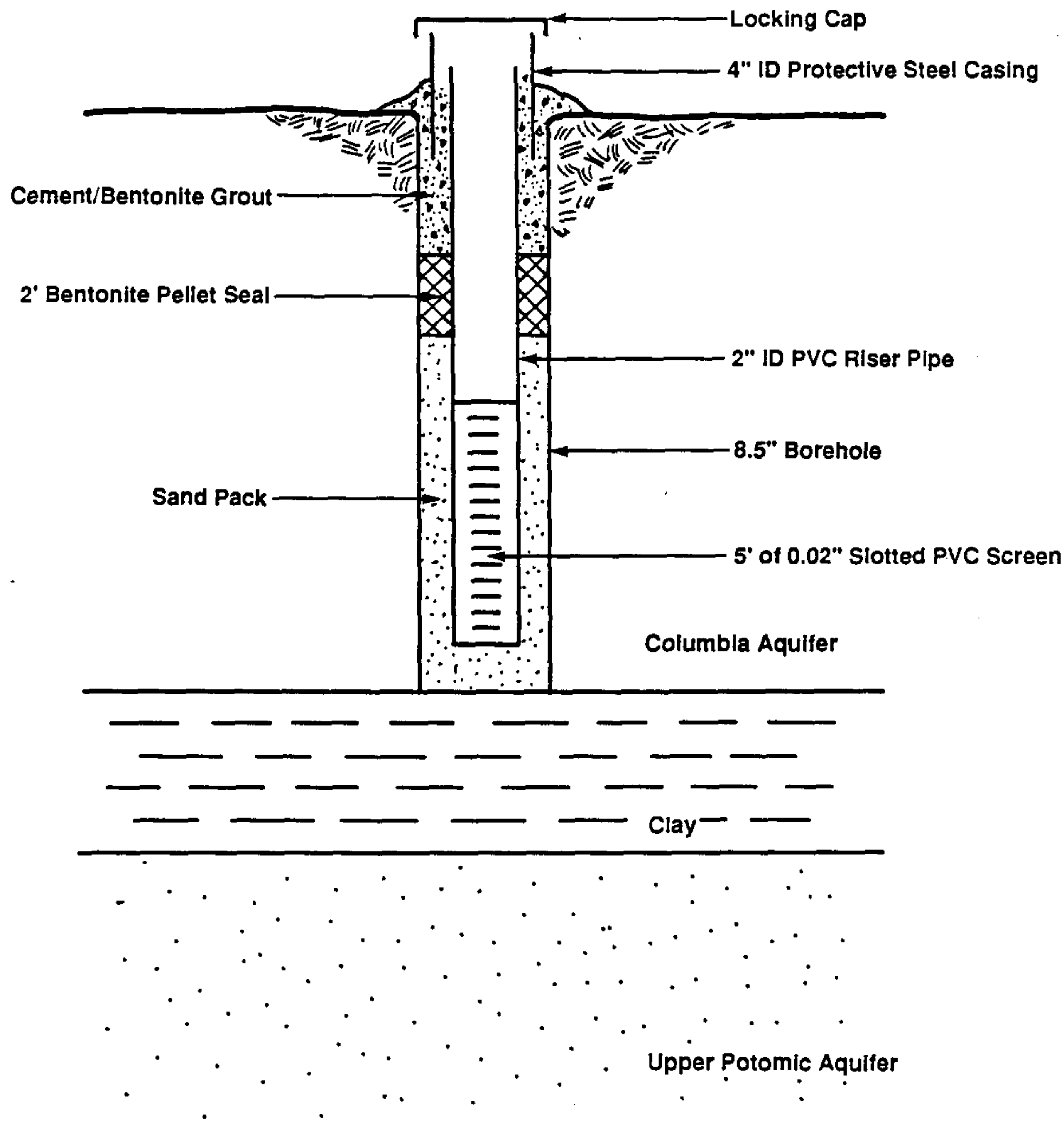
Exceptions to these construction specifications occurred in well MW-5 which was located adjacent to the source area. A 10-foot section of 8-inch ID steel surface casing was grouted into place to minimize the potential of carrying potentially contaminated sediment encountered near land surface down into the screened interval.

In addition to the five new monitoring wells, one 6-inch diameter pumping well labeled PW-1 was installed in the center of the source area. This well was constructed of 6-inch ID schedule 40 PVC riser and 11 feet of .020-inch slotted screen in order to fully penetrate the saturated interval of the Columbia Aquifer. Steel casing (i.e., 14-inch ID) was also set in well PW-1 which extended from land surface to a depth of 8.75 feet. An "as built" diagram for well PW-1 is shown in Figure 3-5.

Before drilling the first well, between wells, and after drilling the final well, all drilling, measuring, and sampling equipment (i.e., augers, drill steel, bits, samplers, wrenches, and other equipment) that contacted potentially contaminated soil or water was steam cleaned. The drill rig was also steam cleaned to remove mud and contaminants from the drill platform and adjacent areas. After being washed, all equipment was rinsed with potable water supplied by NCBW&L. Wash water and sediment from the decontamination procedure were placed in containers.

Newly installed wells were developed with a centrifugal pump until pH and conductivity stabilized and a minimum of three casing volumes were removed. Purged water was placed in

Figure 3-4
Monitoring Well Construction Schematic
New Castle Spill Site



Not to Scale

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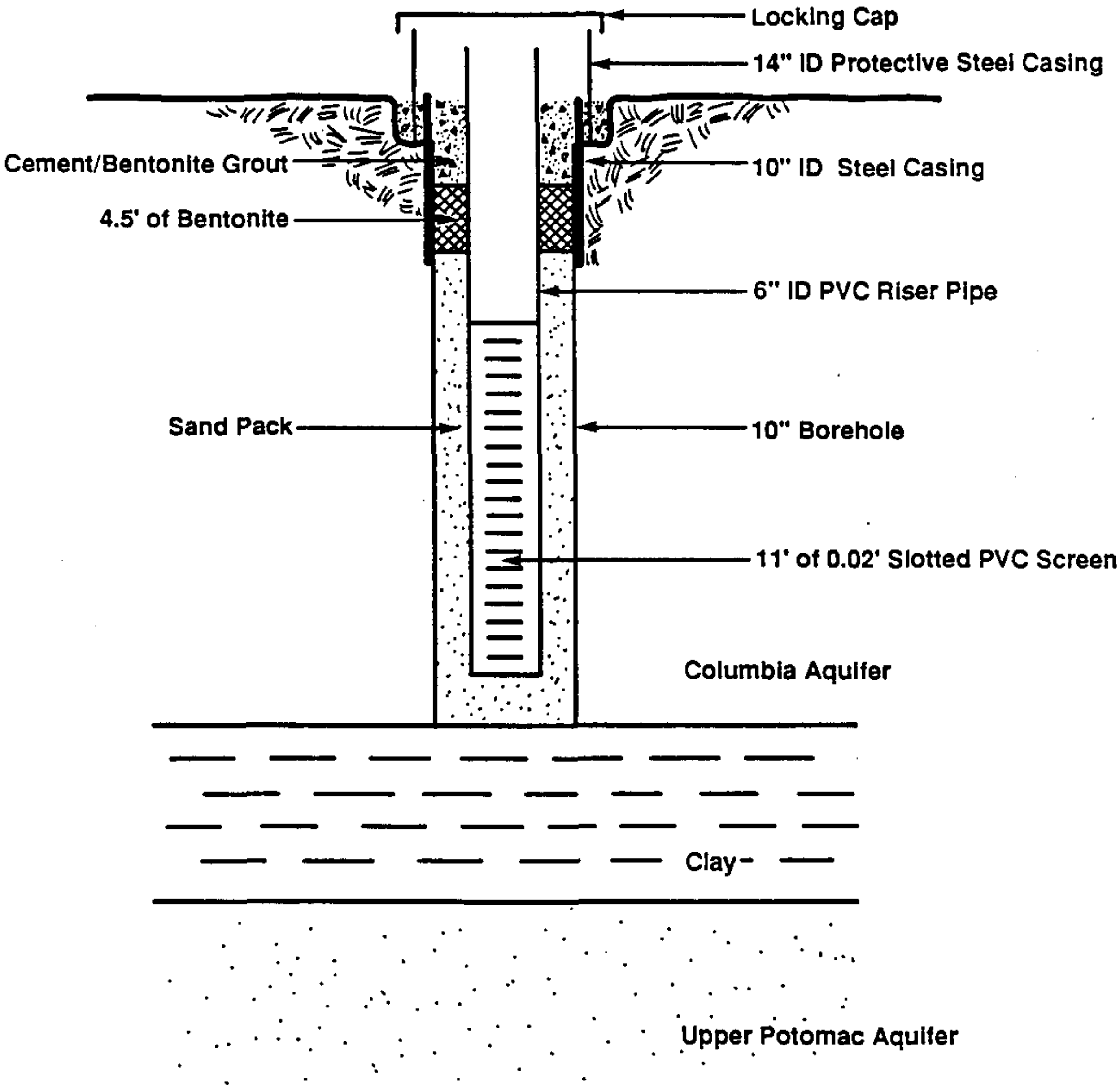
Figure 3-5
Pumping Well Construction Schematic
New Castle Spill Site



Not to Scale

containers and transported off site for treatment. All downhole equipment used for well development (i.e., poly pipe, clamps, foot valves) was precleaned and dedicated to each well to prevent cross-contamination.

At the completion of drilling operations, horizontal and vertical locations of all new wells and existing wells were surveyed by Vandermark and Lynch of Wilmington, Delaware (Appendix D). Horizontal locations were established using the Delaware State System of Plane Coordinates South Zone. Precision of the horizontal traverses are 1/10,000, and the vertical elevations are to the nearest 0.01 foot. Table 3-1 lists the elevations at the top of the PVC casing for new and existing wells monitored during this program. The well construction specifications for existing wells with an "OB" prefix were obtained from existing reports (BCM, 1980).

3.4 Water Quality Sampling

Prior to purging and water quality sample collection, a complete round of depth to water levels were measured to the nearest 0.01 foot. These head level measurements were used to calculate the volume of standing water in each well and to generate the water table contour maps of the surficial aquifer presented in Chapter 4.

After water level measurements were made, each of the 17 wells planned for sampling was purged. A stainless steel 1.5-inch submersible Fultz® pump was used to evacuate five well volumes from all but two of the wells. Existing wells OB-28 and OB-2 were silted-in, and, in order to avoid damaging the pump, these wells were hand bailed. Three well volumes were removed from these two wells. The submersible pump was rinsed with distilled water on the outside, and approximately 2 gallons were run through the pump between wells. Bailers used for purging were pre-cleaned and dedicated to each well. Purge water was containerized and transported off site for treatment.

Dedicated, pre-cleaned, bottom-loading PVC bailers were used to collect samples. In most cases ground water samples were dispensed into the appropriate prelabeled sample bottles directly from the bailer. In those cases where oversight contractors collected samples, dedicated "pouring jars" were rinsed three times and filled with sample and then distributed to the respective sample jars.

The pH, specific conductance, and temperature of each water sample were measured in the field during sampling. All samples collected for metals analysis were filtered through a 0.45 micron pore-sized membrane and transferred into bottles previously spiked with dilute nitric acid preservative. The filtration apparatus was rinsed with dilute nitric acid, methanol, and distilled water between each use. A Millipore filtering system was used.

One matrix spike and matrix spike duplicate sample was collected to satisfy QA/QC requirements. Additionally, field blanks were collected each day during sampling and accompanied all samples during sample collection and in transit to the laboratory. Analytical parameters and detailed sample handling procedures are outlined in Section 3.6. DNREC's oversight contractor (CDM) accepted five split samples and NCBW&L's oversight contractor (BCM) split samples for nine wells (Table 3-3).

TABLE 3-3

LIST OF WELLS SAMPLED BY ERM AND OVERSIGHT CONTRACTORS AT THE NEW CASTLE SPILL SITE

	Wells Sampled		
Well Number	ERM	DNREC	NCBW&L
MW-1	X	X	X
MW-2	X	X	X
MW-3	X		X
MW-4	X	X	X
MW-5	X		X
OB-1	X		
OB-2	X		
OB-3	X		
OB-8	X	X	
OB-10	X		X
OB-11	X	X	
OB-16	X		
OB-21	X		X
OB-24	X		X
OB-25	X		X
OB-27	X		
OB-28	X		

DNREC - Department of Natural Resources and Environmental Control
NCBW&L - New Castle Board of Water and Light

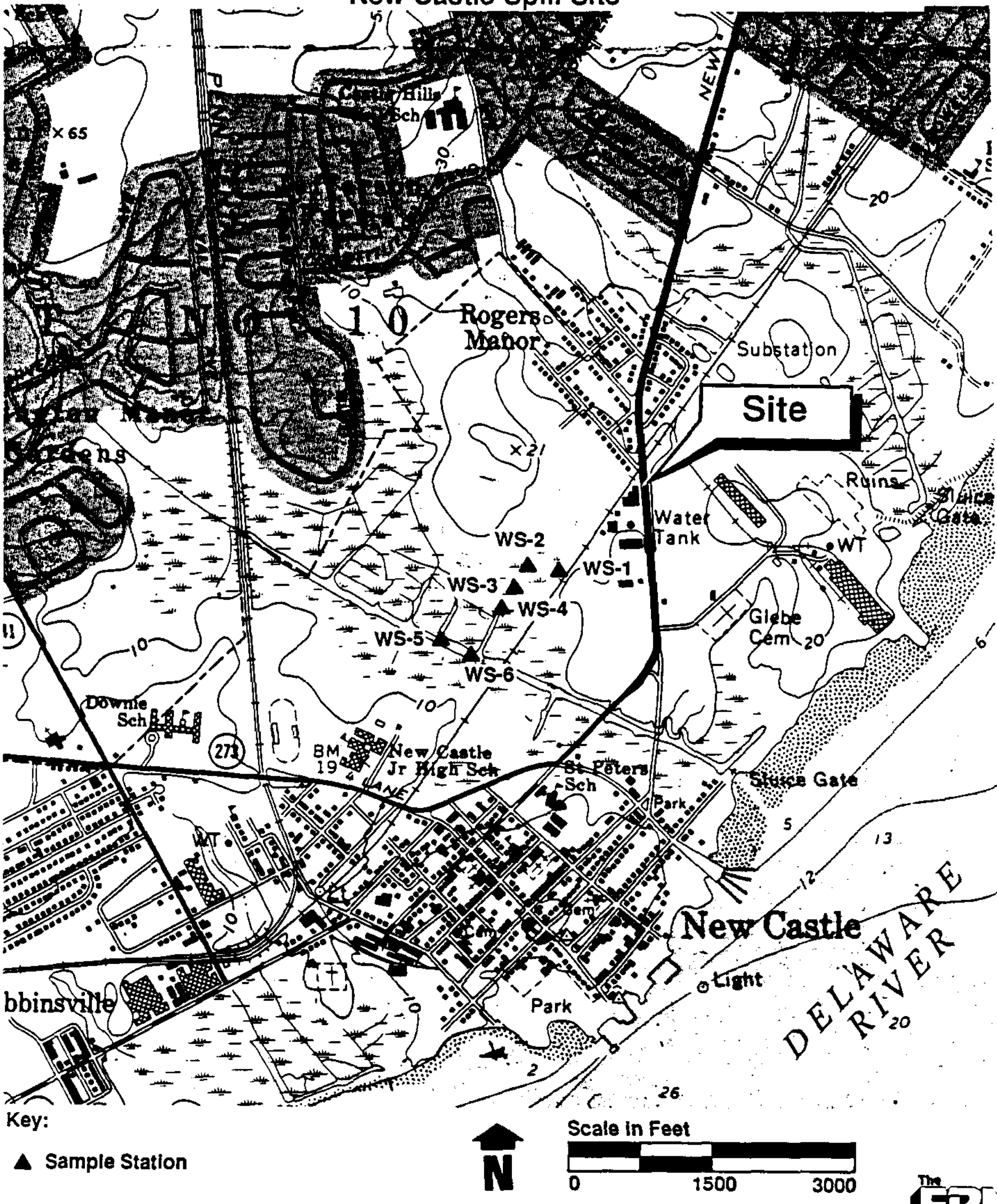
3.5 Wetlands Sampling

As a result of the previous discharge of ground water by the NCBW&L to the wetlands under DNREC direction, surface water and sediment samples were collected to establish the presence or absence of tris. Six sampling locations were agreed upon during a site reconnaissance by U.S. EPA, DNREC, and Witco representatives. A second phase of wetland samples were collected as part of a Phase II investigation recommended by DNREC. Additionally, a macroinvertebrate study was incorporated into this second phase of sampling. The approximate sampling locations are shown in Figure 3-6. The sampling locations follow the anticipated direction of surface water flow from the study area.

Both the Phase I and Phase II surface water samples were collected directly into the appropriate sample container, and care was taken not to disturb the bottom sediments. The inclusion of disturbed sediments in the surface water samples was minimized by sampling the downstream point first, then working upstream. When wading into the stream was necessary, samples were collected upstream from the disturbance caused by wading. In addition to collecting field measurements of pH, specific conductance, and temperature, Phase I surface water samples were submitted for tris analysis from each wetlands sampling location. During Phase II, surface water samples were recollected and analyzed for tris and TCE.

Phase I sediment samples were collected at each surface water sampling location and submitted for tris, Total Organic Carbon (TOC) and grain size analysis. Phase II sediment samples were recollected and submitted for tris, TCE, percent moisture, grain size and percent organic carbon from each wetlands sampling location. Each sample was collected using a stainless steel

Figure 3-6
Approximate Locations of Surface Water & Stream Sediment Samples
New Castle Spill Site



Source: USGS 7.5 Min. Topographic Quadrangle; Wilmington South, DE

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trowel, composited in a stainless steel bowl, and transferred to the sample containers. All equipment was decontaminated between samples using rinses of non-phosphate soap solution, tap water, methanol, and distilled water.

3.6 Analytical Parameters and Sample Handling Procedures

Analytical parameters selected for various media collected at the site and the number of samples analyzed, excluding duplicates, are shown on Table 3-4. Analysis for the complete Target Compound List of volatile organic and semi-volatile organic compounds was performed on all Phase I ground water and soil samples collected from 18 April to 21 April 1988 for the Remedial Investigation. Additional samples were collected on 22 June 1988 subsequent to the Phase I sampling event to address the data gaps identified by the Phase I analysis. Phase II sampling and analysis included TCL volatiles from well OB-30 and tris from both wells OB-8 and OB-21, while a soil sample collected in proximity to well OB-21, was submitted for tris analysis. Surface water samples collected on 14 March 1988 for the Phase I wetland investigation were analyzed for tris, while Phase I sediment samples were analyzed for tris, TOC and grain size. In addition to analyzing for tris, Phase II surface water samples collected on 15 November 1988 were submitted for determination of TCE, dissolved iron and manganese, and salinity concentrations while Phase II sediments were submitted for tris, TCE, grain size, percent moisture, percent organic carbon and total organic carbon analysis.

Tris is not an TCL semi-volatile organic compound, but has been identified as a predominant organic chemical on site. As a tentatively identified compound, it would have been semi-qualitatively and semi-quantitatively identified in the additional peak analysis. To avoid this, a tris standard was

Table 3-4
Summary of Number of Samples
and Type of Analyses Conducted
New Castle Spill Site

Media/location Sampled	Total Number of Samples	TCL Volatiles (+15)	TCL Semi-Volatiles (+30)	TCL Pesticides and PCBs	TCL Inorganics	Tris	TCE	TOC	BOD	COD	TSS	Iron/Manganese Dissolved	Iron/Manganese Total	Salinity	Total Cyanide/ Phenols	% Moisture	Grain Size	% Organic Carbon	Permeability Testing
Soils	15	X	X			X													X(5)
OB-21	1					X													
Ground Water	17	X	X			X		X		X		X							
OB-8*	1					X													
OB-21*	1					X													
OB-30*	1	X																	
PW-1	1	X	X	X	X	X			X		X				X				
PW-1 During Pump Test	2	X	X			X		X		X		X			X				
Surface Water	6(I)					X													
	6(II)					X	X					X	X	X					
Sediment	6(I)					X											X(3)		
	6(II)					X	X	X								X	X	X	

(I)=Phase I of the Wetlands Investigation
(II)=Phase II of the Wetlands Investigation
X(3)=Indicates Analyses Conducted on Three Samples
X(5)=Indicates Analyses Conducted on Five Samples
* Phase II groundwater samples

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added to the TCL semi-volatile organic fraction to provide qualitative and quantitative analyses.

Laboratory cleaned jars with teflon-lined lids were provided by I-Chem Research of New Castle, Delaware. Before sampling, an adhesive identification label was affixed to each container, and each was checked for completeness before the samples were placed in insulated coolers where the samples were kept at about 4°C. The samples were shipped by overnight courier to Cambridge Analytical Laboratory of Boston, Massachusetts.

Additional information for quality control, quality assurance and chain of custody procedures are included in the Quality Assurance Project Plan (QAPP) which is an attachment to the RI/FS Work Plan (ERM, 1988).

Stainless steel spoons, trowels, and bowls were used during the collection and compositing of soil and sediment samples. All utensils were decontaminated by washing with a non-phosphate soap solution followed by a tap water rinse, methanol rinse and triple distilled water rinse prior to use and between samples. PVC bailers used during ground water sampling were cleaned by the above procedure. Split spoon samplers used during the drilling program to collect soil samples were steam cleaned prior to use and cleaned by the above procedure between samples.

3.7 Aquifer Testing

A 24-hour pump test was conducted to determine the effect of ground water withdrawal on the configuration of the water table within the shallow aquifer (Columbia Aquifer). Additionally, aquifer characteristics (transmissivity and storativity) were to be determined using recognized methods for pump test data analysis. All water level data obtained during the 24 hour pump test are included in Appendix E.

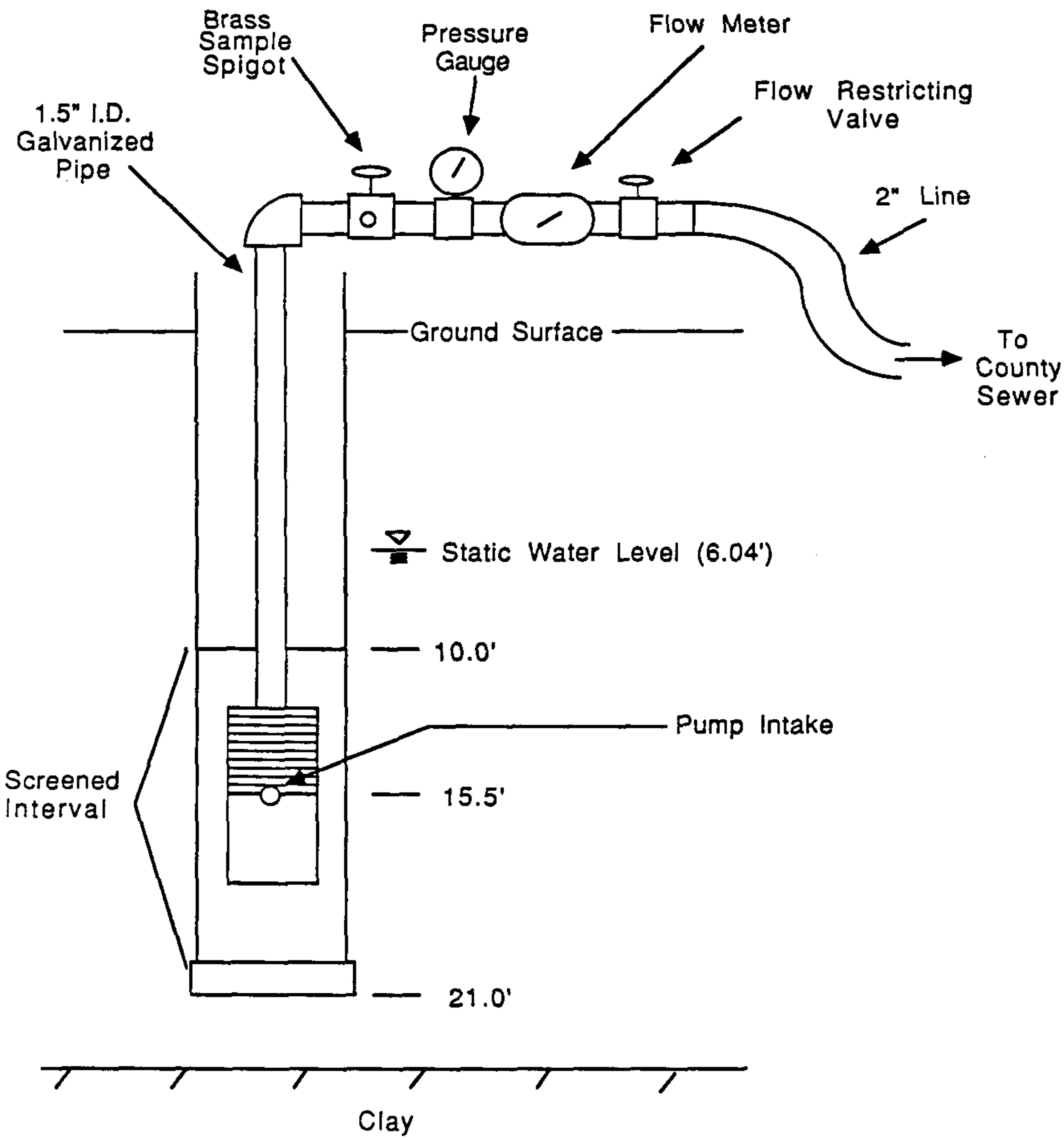
The pump test was conducted by placing a 4-inch submersible pump within the newly installed pumping well (PW-1), located centrally within the recognized spill source area on the NCBW&L property. The pump was installed centrally within the screened interval where the pump intake was approximately 5.5 feet above the bottom of the well. All purge water produced from the production well during aquifer testing was disposed of into the county sewer system with the permission of DNREC, the City of Wilmington, and the New Castle County Sewer Authority. Figure 3-7 is a schematic diagram of the pumping apparatus utilized to facilitate pumping of the production well.

Before the pump test was begun, well PW-1 was pumped to redevelop the well and to determine the appropriate flow rate to produce the desired amount of drawdown during the pump test. Redevelopment was deemed necessary because the anticipated pumping rate of 40 to 50 gpm was higher than the 20 gpm rate used to initially develop the well after installation.

PW-1 was redeveloped at a pumping rate of 35 gpm for approximately 1 hour. Purge water from the redevelopment phase of preliminary pumping was clear and free of turbidity. During well development, the water level within the pumping well was monitored during pumping and recovery of the water level to static conditions. The preliminary information collected during redevelopment of PW-1 was used for subsequent testing to determine the optimum flow rate for the pump test.

Subsequent to well redevelopment, PW-1 was step tested to determine the long-term effects of various flow rates on drawdown within the pumping well. Water levels during the step testing of

Figure 3-7
Schematic Diagram of the Pump Test
New Castle Spill Site



PW-1 were collected using a Hermit® data logger. Step testing commenced at a flow rate of 33 gpm, and this flow rate was sustained for a period of 130 minutes. Then the flow rate was increased to approximately 36 gpm. At 180 minutes, the flow rate was again increased to 38 gpm, which was the maximum sustainable output.

The 24-hour pump test began at 1300 hours on 12 May 1988 and was terminated at 1340 hours on 13 May 1988. The average rate of discharge during the pump test was 36 gpm, with actual pumping rates fluctuating between 38 and 34 gpm over the duration of the test. In addition to the pumping well, the drawdown in six other wells completed within the Columbia aquifer (MW-1, OB-5, MW-2, OB-24, MW-3, OB-3) was monitored by the Hermit® data loggers. These wells were monitored by Hermits® to provide simultaneous measurements of nested wells. The other wells were monitored hourly by ERM personnel, and depth to water measurements were recorded in a site dedicated field book. Figure 3-8 designates the wells monitored by Hermit® data loggers, and those wells monitored manually by ERM personnel.

3.8 Phase II Environmental Assessment Methodology

An investigation of wetland areas adjacent to the New Castle Spill Site was conducted to characterize habitats, identify target populations (potential receptors) and determine possible spill impacts. Two surveys, a wetland delineation/habitat assessment and a qualitative macroinvertebrate study, were performed to achieve the objectives stated above. Data obtained from these surveys were then used to assess possible impacts to the surrounding flora and fauna.

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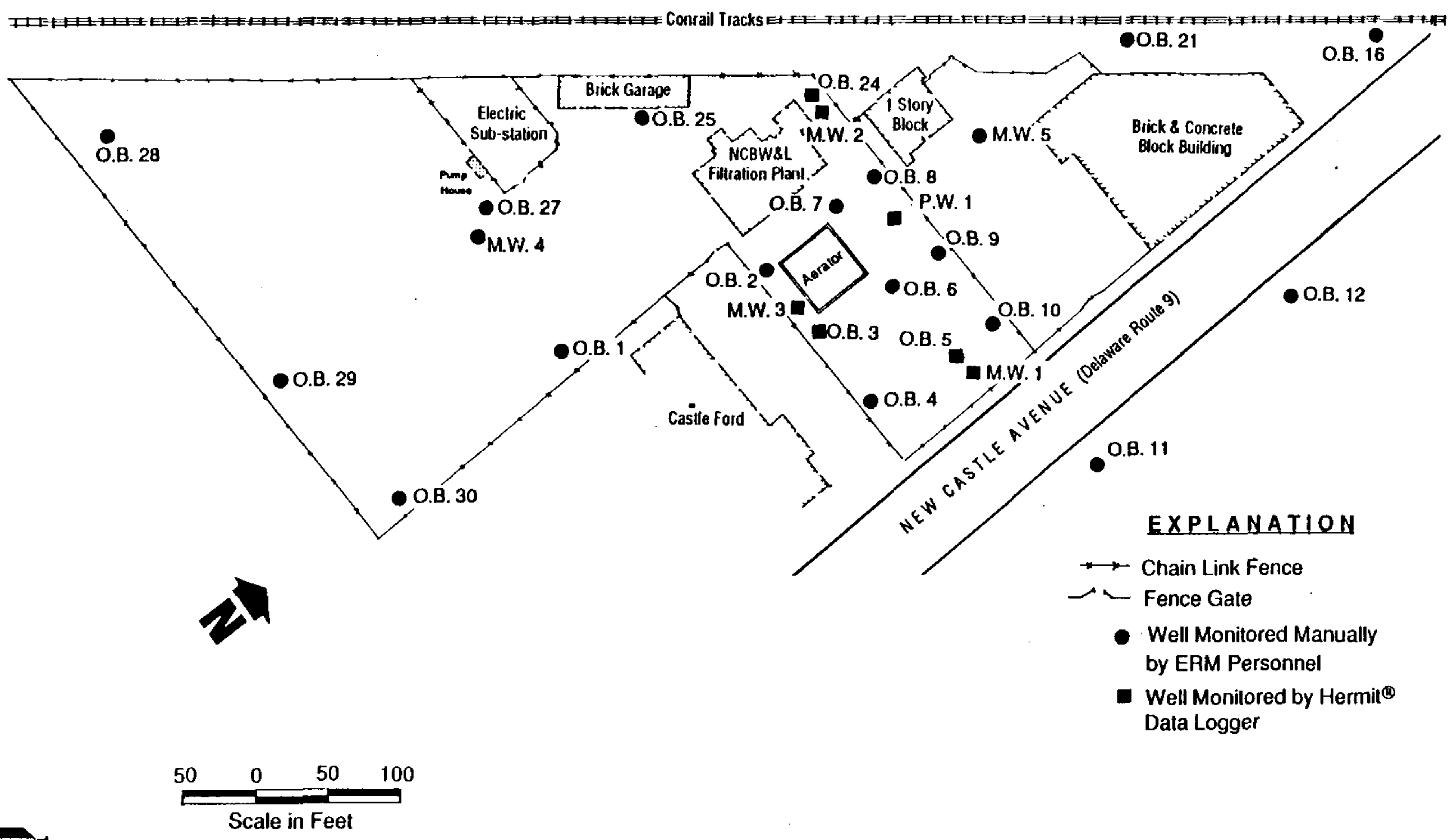
Figure 3-8
Monitoring Wells Included in the 24-Hour Pump Test
New Castle Spill Site



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3.8.1 Wetland Delineation/Habitat Assessment

In November 1988, a qualitative inventory of vegetation and wildlife was conducted. The objectives of the survey were to characterize wetland habitats, identify target populations, and to assess possible spill impacts. Wildlife was inventoried based on actual observations, supplemented by observations of scat, bird calls and animal tracks. Appropriate taxonomic references and field guides were employed for plant and bird identifications. Letters were written to DNREC, Division of Parks and Recreation-Natural Heritage Program and the Division of Fish and Wildlife for information concerning rare, threatened, or endangered species of plants, fish, reptiles, amphibians, birds and mammals that may inhabit the study area.

The wetland areas were delineated and classified based on U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory Maps, Delaware State Wetland Maps, Cowardin System and field reconnaissance. The U.S. Army Corps of Engineers (USCOE) three-parameter approach to wetland identification and delineation was used during the field reconnaissance. These three-parameters include vegetation, soil type and hydrology.

Vegetation

Plants characteristically dominating wetland areas are collectively referred to as hydrophytes. To help identify wetland areas, the USCOE has assigned a wetland indicator status category to many plants that have been found in wetland areas. The wetland indicator status category defines the estimated probability of a plant species occurring in wetlands as follows (USCOE 1987):

Category	Estimated Frequency of Occurrence in Wetlands
Obligate Wetland Plants (OBL)	>99%
Facultative-Wet Wetland Plants (FACW)	67% to 99%
Facultative Wetland Plants (FAC)	33% to 67%
Facultative Upland Plants (FACU)	1% to 33%
Upland Plants (U)	<1%
Undecided (?)	

Soils

Wetland soils are collectively referred to as hydric soils. Hydric soils are those soils that are either permanently or periodically deficient in oxygen as a result of water saturation. Certain soil series identified through USDA Soil Surveys have been designated as hydric soils by the USCOE, and the presence of these soils typically indicates an area exhibiting wetland characteristics.

Hydric soils are determined visually by soil color, since color can indicate whether a soil is subject to constant saturation, a fluctuating water table, or is well drained. Soil colors are determined by comparing soil sample colors with color strips in a Munsell Soil Color Chart. Munsell colors for soils are documented in a symbolic notation identifying the hue, value, and chroma of a given soil color. An example of soil color notation is 5 YR 7/1. The hue is represented by 5 YR (yellow-red); the value is noted at 7 and the chroma as 1.

Soils characteristic of well-drained, aerated areas are brightly colored, whereas soils subject to a fluctuating water table either have bright mottles (patches of varying color) and low soil matrix chroma (two or less) or have no mottles and a soil matrix chroma of one (USCOE, 1987). Constantly saturated, waterlogged soils typically have low chroma or are gray in color. These soils are often referred to as gleyed soils.

Hydrology

The hydrology of a wetland is such that the area is inundated either permanently or periodically at a mean water depth equal to or less than 6.6 feet or that the soil is saturated for a prolonged period of time by ground water during the growing season.

3.8.2 Macroinvertebrate Survey

In response to DNREC comments, a macroinvertebrate survey was conducted to identify and characterize the benthic macroinvertebrate community. This information was then utilized to assess the quality of the wetland habitat.

Background Information

Bottom fauna organisms are those aquatic invertebrates that live in, crawl on, or attach to the bottom substrate of a body of water. Bottom organisms that will not pass through a No. 30 U.S. Standard sieve (0.0232 inch openings or 0.59 mm) are referred to as macroinvertebrates, benthic macroinvertebrates, or just benthic organisms.

Macroinvertebrates include organisms such as stonefly nymphs, mayfly nymphs, caddisfly larvae, scuds, damselfly nymphs, dragonfly nymphs, midge fly larvae, leeches, crabs, mussels, clams and aquatic worms.

Bottom fauna are good indicators of polluted water for several reasons. First, many species are extremely sensitive to pollution. Second, benthic organisms usually have a complex life cycle of a year or more, resulting in long-term exposure to ambient conditions. Third, bottom fauna are not capable of rapid migration during periods of stress because of their attached or sessile mode of life.

Unpolluted water will support many kinds of benthic organisms, but the number of individuals, with a few exceptions, representing each kind will be low. Polluted water stresses the sensitive organisms and causes them to die, while the tolerant species increase in numbers. Therefore, in polluted water there will be only a few species represented, but generally greater numbers of total organisms.

Sample Collection

Qualitative macroinvertebrate samples were collected based on the procedures outlined in U.S. EPA. 1973. Biological Field and Laboratory Methods for Measuring the Quality of Surface Waters and Effluent, from locations corresponding to the existing six surface water and sediment sampling stations. Samples were obtained from the bottom sediments, to an approximate depth of 3 inches, using an Eckman dredge (6 inch x 6 inch). Samples were then field sieved using a 0.5 mm mesh sieve bucket. Organisms and detritus retained in the sieve bucket were then transferred to wide mouth jars and stained with Rose Bengal solution prior to preservation with 70 percent isopropyl alcohol. Each sample was completely sorted and identified to the lowest possible taxon using the appropriate taxonomic keys and guides. Diversity calculations were not performed due to the qualitative nature of the study and limited number of specimens collected.

SECTION 4

RESULTS OF INVESTIGATIONS

4.1 Well Inventory

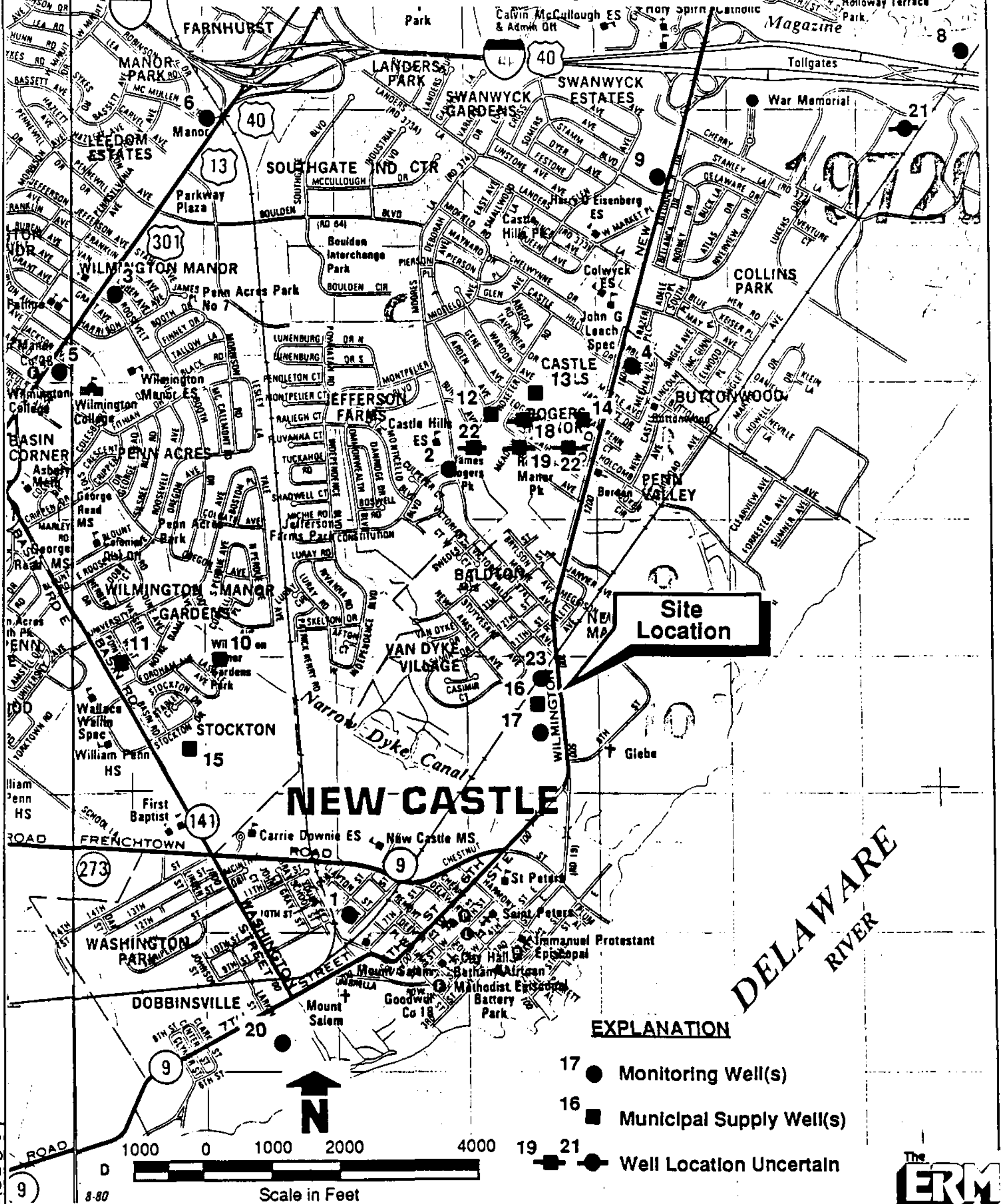
A well inventory was conducted at the state offices in Dover, Delaware on 7 July 1988. This inventory was conducted to identify wells which could potentially be impacted by past activities at the New Castle Spill Site. The area investigated extended approximately two miles north, and one mile south of the site.

Seventy-four existing wells completed in the Columbia or Potomac formations were identified within the area investigated. Fifty-four of the 74 wells were used for monitoring purposes. Four wells were identified as industrial supply wells while ten wells were identified for use as municipal supply wells withdrawing water from the Potomac formation. Eight of these municipal supply wells are owned by Artesian Water Company, while two wells are owned by the NCBW&L. Additionally, four wells have void permits while two wells have permits pending. Figure 4-1 shows the locations of wells identified in the well inventory. Table 4-1 gives the owners, the aquifer in which each well is completed and the use for each well.

4.2 Tidal Fluctuation Study

The Tidal Fluctuation Study was conducted on 11 February 1988. The study began at 0940 hours and ended the following day at 1200 hours. Water levels were recorded using Hermit® data loggers in observation wells OB-11, OB-12, OB-28, and production well 11

Figure 4-1
Location of Wells Identified in the Well Inventory



ORIGINAL

Table 4-1
Wells Identified in Well Inventory
New Castle Spill Site

Location Number	Owner	Number of Wells	Aquifer	Use
1	Deemer Steel	5	Columbia	Monitoring
2	Atlantic Richfield	6	Columbia	Monitoring
3	Amoco	4	Columbia	Monitoring
4	Exxon	4	Columbia	Monitoring
5	Merit	4	Columbia	Monitoring
6	Chevron	1	Columbia	Monitoring
7	Texaco	9	Columbia	Monitoring
8	The Crouse Group	2	Columbia	Monitoring
9	Atlantic Richfield	3	Columbia	Monitoring
10	Artesian Water Co.	1	Potomac	Municipal Supply
11	Artesian Water Co.	1	Potomac	Municipal Supply
12	Artesian Water Co.	1	Potomac	Municipal Supply
13	Artesian Water Co.	2	Potomac	Municipal Supply
14	Artesian Water Co.	1	Potomac	Municipal Supply
15	NCBW&L	1	Potomac	Municipal Supply
16	NCBW&L	1	Potomac	Municipal Supply*
17	New Castle County	1	Potomac	Monitoring**
18	New Castle County (water resources)	5	Columbia, Potomac	Monitoring
19	Artesian Water Co.	1	Potomac	Municipal Supply
20	Abex Corporation	4	Columbia	Monitoring
21	ICI Americas Inc.	4	Columbia, Potomac	Industrial
22	Artesian Water Co.	1	Potomac	Municipal Supply
23	Witco Corp.	6	Columbia	Monitoring
Void	Deemer Steel	1	Columbia	Monitoring
Void	Atlantic Richfield	1	not specified	Monitoring
Void	Artesian Water Co.	2	Potomac	Municipal Supply
Pending	Artesian Water Co.	1	Columbia	Monitoring
Pending	Artesian Water Co.	1	Potomac	Monitoring

* Well no longer used

** *Assumed Use*

Void and pending wells are not included on figure 4-1 while water level readings in the remaining 18 wells were obtained on an hourly basis by ERM personnel using an electronic water level indicator. Because of an error in programming the data loggers, the water levels from these 4 wells were not obtained at the specified time intervals. However, water level data obtained from the remaining 18 wells was more than sufficient to assess tidal influences. Figure 4-2 shows the wells which were monitored during the Tidal Fluctuation Study, and Table 4-2 presents the minimum and maximum depth to water measurements and respective elevations obtained from each well during the study.

Figures 4-3 and 4-4 were generated from the data collected during the Tidal Fluctuation Study and show the maximum and minimum ground water elevations, respectively. In both figures, the ground water flow direction is generally to the north across the NCBW&L property and the New Castle Spill Site. In the vicinity of Castle Ford and west toward the marsh area, ground water flow is generally to the west-northwest. The hydraulic gradient from Castle Ford to the marsh area is gentler than that across the front lawn of the NCBW&L property and New Castle Spill Site and reflects a probable ground water mound.

In addition to generating the aforementioned ground water elevation contour maps, the data obtained during the Tidal Fluctuation Study were used to generate hydrographs presented in Appendix F. In these graphs, the depth to water was plotted versus time on an arithmetic scale. In addition, the predicted tidal fluctuations were superimposed as a means of establishing a lag time between tidal and ground water extremes. Based on these graphs, tidal fluctuations have a negligible effect on ground water extremes. Water table contour maps presented in Figures 4-3 and 4-4 do not show changes in ground water flow direction with respect to minimum and maximum ground water elevations. The

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Figure 4-2
Wells Monitored During the Tidal Fluctuation Study of the Water Table Aquifer
New Castle Spill Site

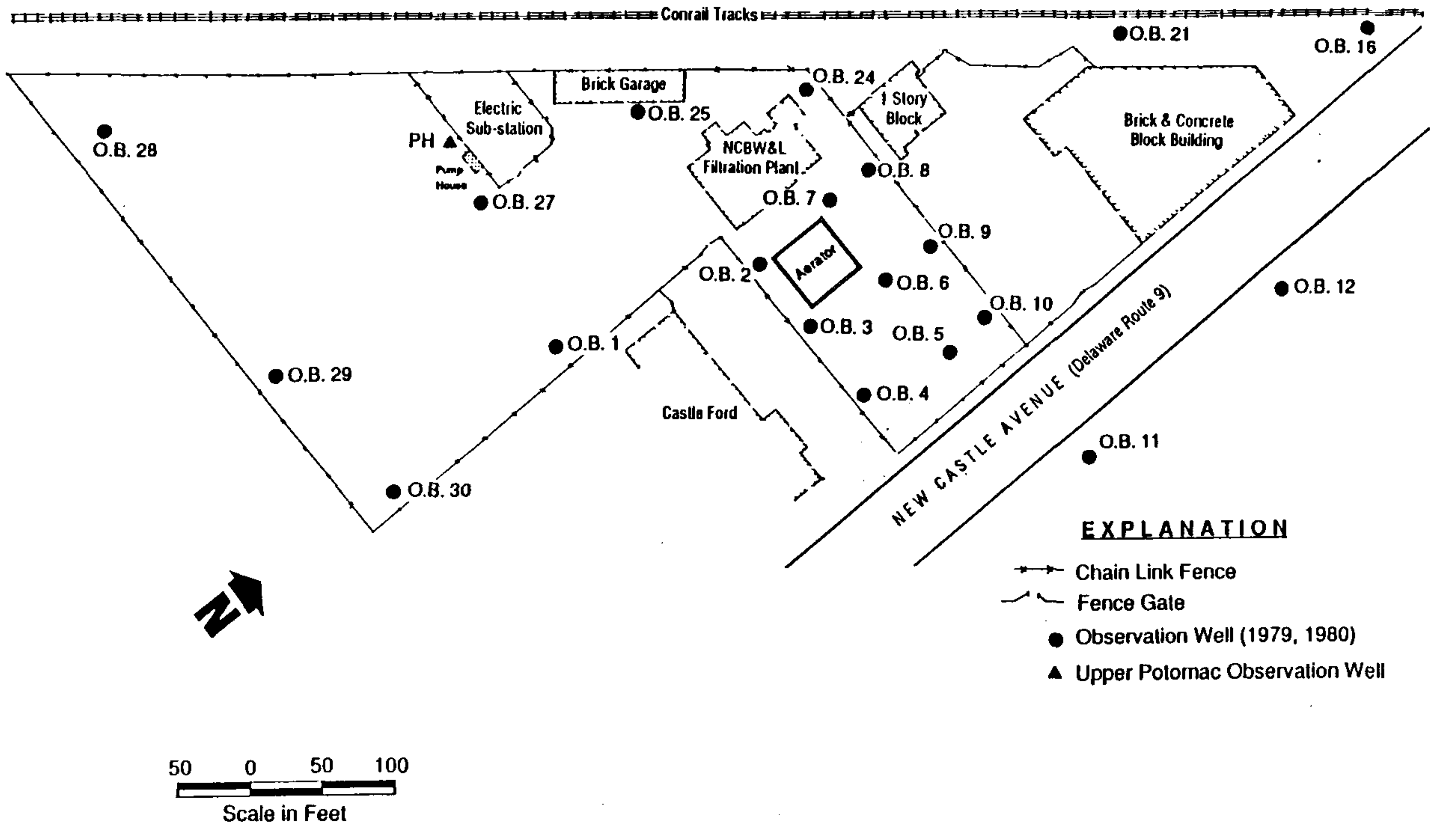

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Table 4-2
Ground Water Elevations Recorded During the Tidal Fluctuation Study
New Castle Spill Site

Well	Elevation TOC	Minimum GW Elevation (0940)		Maximum GW Elevation (2340)	
		DTW	Elevation	DTW	Elevation
OB-1	9.80	8.92	0.88	8.85	0.95
OB-2	6.22	5.43	0.79	5.34	0.88
OB-3	6.99	6.23	0.76	6.19	0.80
OB-4	7.56	6.81	0.75	6.74	0.82
OB-5	8.39	7.66	0.73	7.59	0.80
OB-6	7.77	7.05	0.72	6.97	0.80
OB-7	6.74	5.92	0.82	5.83	0.91
OB-8	5.58	4.87	0.71	4.76	0.82
OB-9	7.00	6.28	0.72	6.19	0.81
OB-10	7.44	6.72	0.72	6.65	0.79
OB-11	9.30	8.55	0.75	ND	ND
OB-12	9.90	9.17	0.73	ND	ND
OB-16	9.26	8.78	0.48	8.72	0.54
OB-21	8.28	7.73	0.55	14.40	-6.12
OB-24	5.54	4.81	0.73	4.65	0.89
OB-25	5.16	4.30	0.86	4.19	0.97
OB-27	8.00	7.17	0.83	7.08	0.92
OB-28	8.28	7.42	0.86	ND	ND
OB-29	11.13	10.28	0.85	0.20	0.93
OB-30	14.33	13.43	0.90	13.35	0.98

ND Data not available

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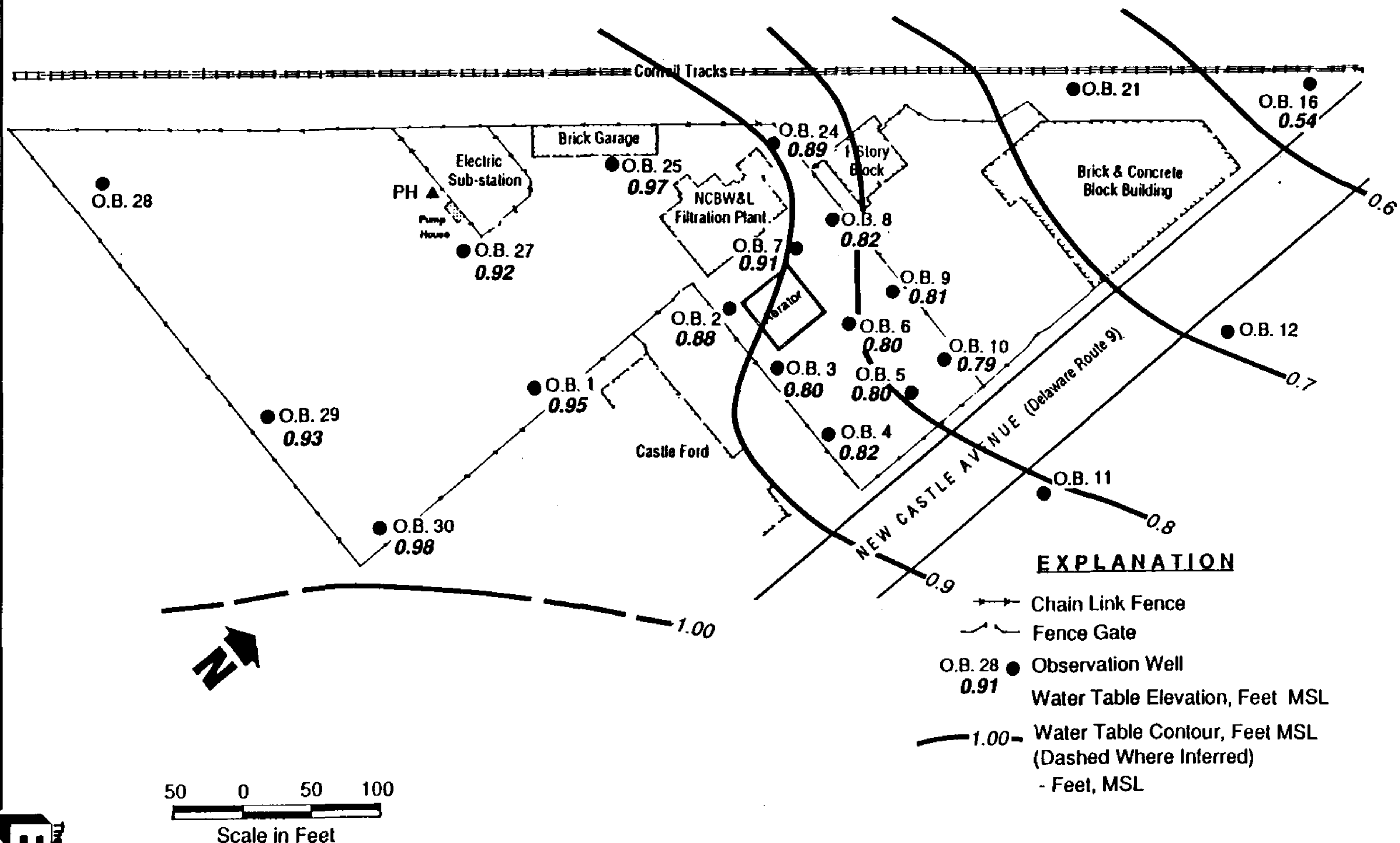
Figure 4-3
Maximum Water Level Elevation Contour Map
Tidal Fluctuation Study - New Castle Spill Site



The ERM Group

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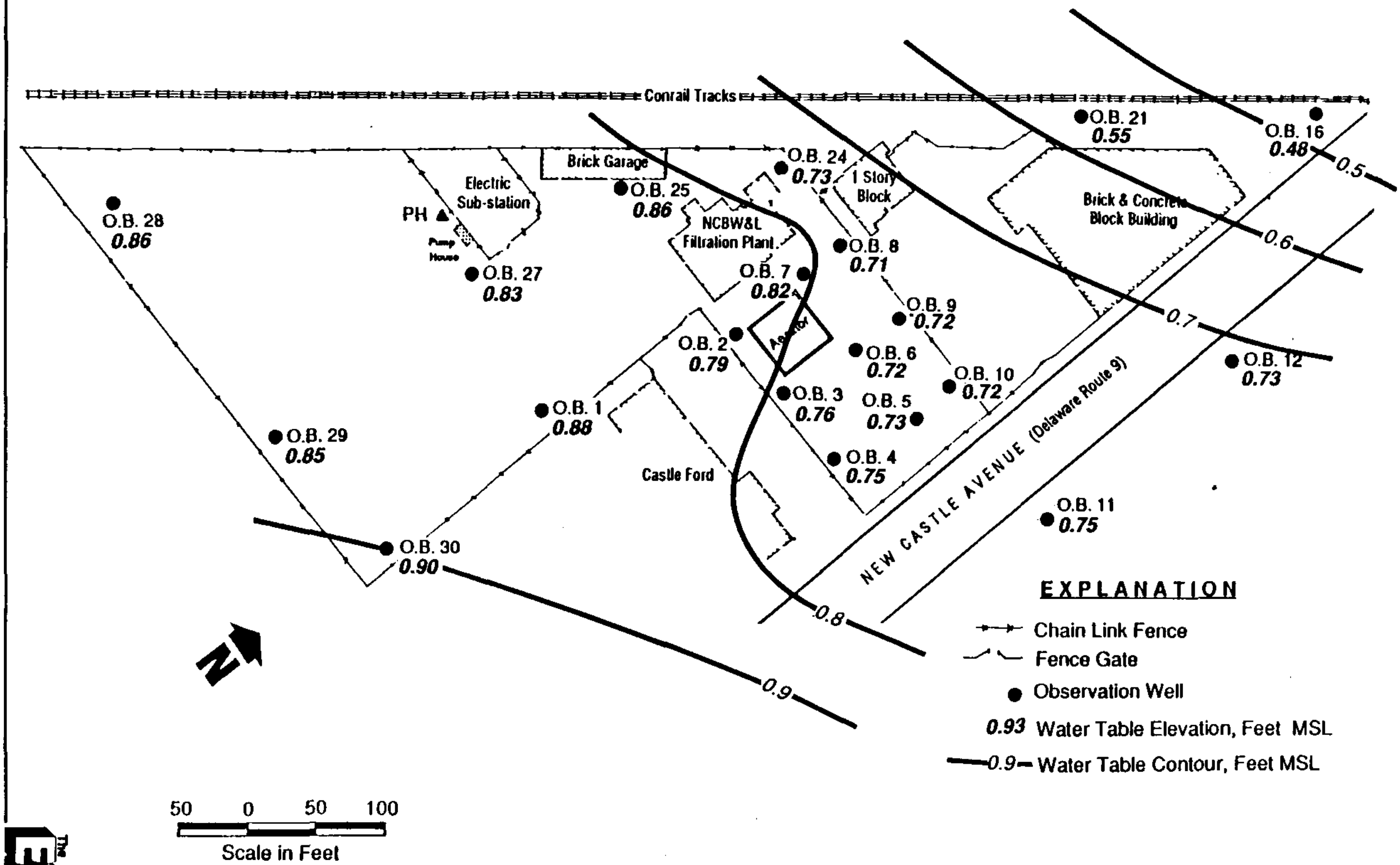
Figure 4-4
Minimum Water Level Elevation Contour Map
Tidal Fluctuation Study - New Castle Spill Site



The ERM Group

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recharge effects of a heavy rainstorm that occurred approximately 14 hours into the tidal study can also be observed on the hydrographs. The storm event began at approximately 2300 hours on 11 February, and recharge began showing up on the hydrographs at approximately 0100 hours on 12 February.

A correlation between tidal and ground water extremes could not be established. Also, the hydrographs did not indicate the influence of offsite pumping activities, therefore, the most likely mechanism for ground water fluctuations are changes in barometric pressure. The barometric pressure data presented in Table 4-3 were obtained and superimposed on the hydrographs derived from the 24-hour tidal study. These graphs are included as part of Appendix D. As indicated by the hydrographs, ground water fluctuations appear to be directly influenced by barometric changes. The general trend of decreasing barometric pressure over the course of the tidal study appears to be the factor responsible for increasing the ground water elevation. This trend was observed for data obtained before 1200 hours on 12 February when recharge from the storm event increased the ground water level.

4.3 Site Geology/Hydrogeology

During the soil boring program of March 1988, three predominant stratigraphic units were encountered: a surficial clay and silt layer, a sand layer, and a clay layer. Figure 4-5 shows the relative orientation of the different stratigraphic units encountered during borehole advancement for the newly installed monitoring wells.

The surficial layer consisted of a variable sequence of clay, silty clay and silty sand materials which ranged in thickness from 4.5 feet in boring B-2 to 10.3 feet in well MW-2. The

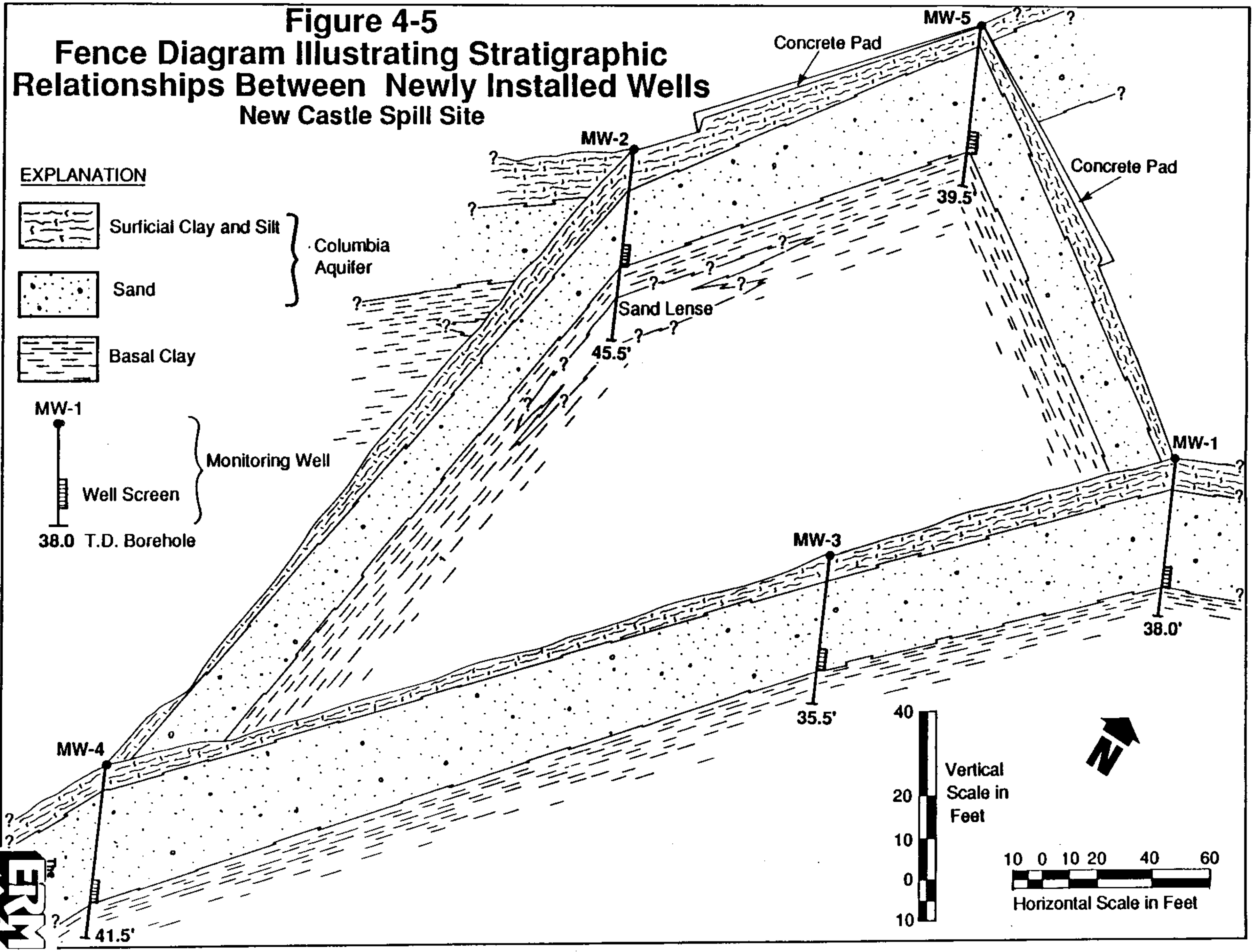
TABLE 4-3

BAROMETRIC PRESSURE RECORDED AT THE GREATER WILMINGTON AIRPORT
11 - 12 FEBRUARY 1988

11 February 1988		12 February 1988	
Time	Barometric Pressure (Inches of H_g)	Time	Barometric Pressure (Inches of H_g)
0100	30.47	0100	30.07
0200	30.47	0200	30.01
0300	30.47	0300	29.95
0400	30.48	0400	29.92
0500	30.48	0500	29.88
0600	30.48	0600	29.80
0700	30.49	0700	29.75
0800	30.50	0800	29.72
0900	30.50	0900	29.72
1000	30.50	1000	29.72
1100	30.50	1100	29.67
1200	30.50	1200	29.62
1300	30.48	1300	29.62
1400	30.45	1400	29.62
1500	30.41	1500	29.58
1600	30.39	1600	29.55
1700	30.37	1700	29.54
1800	30.37	1800	29.53
1900	30.36	1900	29.53
2000	30.34	2000	29.58
2100	30.31	2100	29.51
2200	30.25	2200	29.61
2300	30.19	2300	29.62
2400	30.11	2400	29.62

Source: National Weather Service

Figure 4-5
Fence Diagram Illustrating Stratigraphic Relationships Between Newly Installed Wells
New Castle Spill Site



average thickness of the surficial layer was 6.7 feet. A conspicuous fill layer, consisting of slag or resin type material in a brown silty matrix was observed within the surficial layer. This material was present in all boreholes, with the exceptions of borings B-2, B-3 and MW-4. The thickness of the fill layer ranged from 0.2 feet in boring B-1 to 3.0 feet in well MW-5 located on Witco's property. The average thickness of the fill layer observed across the NCBW&L property was 0.5 feet.

Underlying the surficial clay and silt layer was the Columbia aquifer consisting of medium-grained sand containing abundant fine quartz gravel clasts. This sand layer ranged in thickness from 17.7 feet in MW-2, to 28.7 feet in MW-4, and averaged 23.5 feet in thickness.

Underlying the Columbia aquifer was a very dense, stiff clay layer designating the top of the Potomac Formation within the study area. This clay layer ranged in depth from 25 feet in well PW-1 to 34 feet in well MW-4, and had an average depth of 29.8 feet. Permeability tests of the clay were conducted on Shelby tube samples collected from wells MW-1, MW-3, MW-4, MW-5 and PW-1. A Shelby tube sample was not obtained from well MW-2 as a result of the presence of a fine grained, well sorted sand lense at a depth of 35.5 feet. Because this sand was encountered only in well MW-2, its geometry can only be approximated. However, its conspicuous absence in the other newly installed wells defines this sand lense as discontinuous within the study area. The sand lense depicted as part of well MW-2 in Figure 4-5 depicts both this discontinuous nature and uncertain geometry. The presence of this sand lense is consistent with published descriptions of the Potomac Formation. Pump test and water quality data discussed in Section 1.3.4, as well as vertical permeability test data (Section 4.3.2), indicate that the Columbia and Potomac aquifers are not connected. Figure 4-6 depicts the structure of the top of the clay unit across the site.

Water levels obtained on 30 March and 18 April 1988 were converted into elevations and used to construct the ground water table contour maps shown in Figures 4-7 and 4-8. Across most of the study area, the ground water flow direction is generally to the north. However, in the vicinity of Castle Ford, the ground water flow direction is generally in a northwest direction, and it discharges to the marsh adjacent to the study area.

Newly installed wells MW-1, MW-2, MW-3, and MW-4 were paired with existing wells screened at a shallow depth within the shallow aquifer. The well nests allow for measurement of the potential vertical gradients between wells. Based on the water levels obtained from the well nests, upward vertical gradients of 0.3 and 0.1 feet have been defined in nested wells MW-4/OB-27 and MW-3/OB-3 respectively. Water levels obtained from the other nested wells (MW-2/OB-24 and MW-1/OB-5) were within 0.02 feet of each other and do not indicate the existence of a vertical gradient. Table 4-4 presents the water level measurements obtained on 30 March and 18 April 1988 in terms of depth to water below top of casing and ground water elevation in feet above mean sea level.

In addition to defining head relationships between the "OB" series and "MW" series wells, head relationships between the shallow Columbia Aquifer and the deeper Potomac Aquifer were examined. Wells OB-27 and PH were used to facilitate inspection of these relationships.

The water level data included in Table 4-4 indicate a head differential of 5.75 feet between wells OB-27 and PH on 30 March 1988. With an aquifer separation of approximately 85 feet, the

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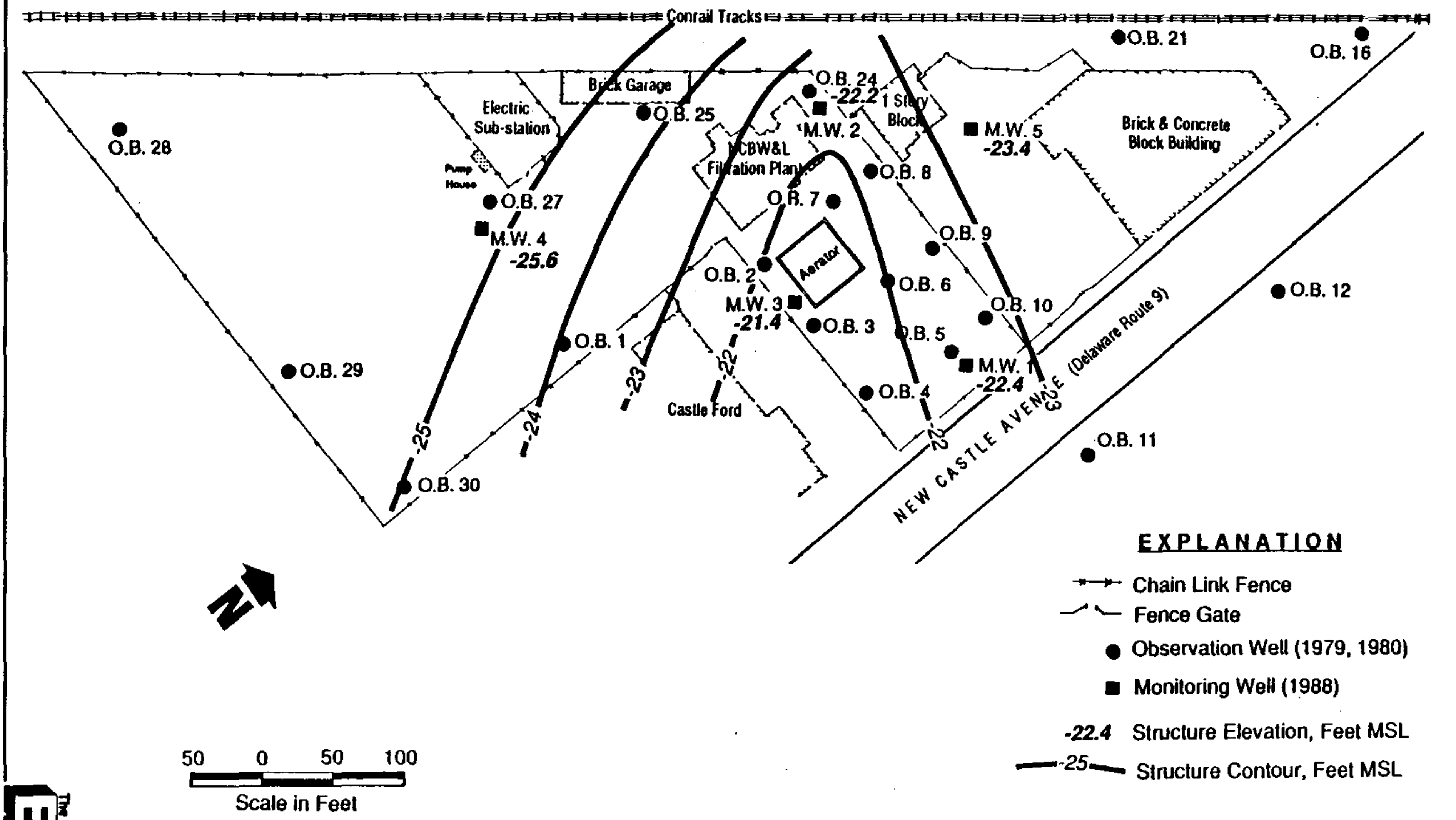
Figure 4-6
Structure of the Top of the Clay Unit, Potomac Formation
New Castle Spill Site



The ERM Group

ORIGINAL
(Red)

resulting vertical gradient is 0.07 in a downward direction. However, the water level in well PH rises above the clay confining layer and thus, exhibits artesian conditions. These artesian conditions are supportive of the clays continuity within the study area.

Based on the ground water table contour map of 18 April 1988 (Figure 4-8), the ground water beneath most of the NCBW&L and New Castle Spill Site properties flows in a northerly direction with an average hydraulic gradient of 0.09 feet per 100 feet. This parameter was calculated using the following equation:

$$I = \frac{h_2 - h_1}{l}$$

where:

h_2-h_1 = difference in hydraulic head between two points located on the same ground water flowline

l = horizontal distance between these same two points measured along the same ground water flowline

The horizontal ground water flow rate (V) was calculated using the following equation:

$$V = \frac{KI}{n_e}$$

where:

K = average hydraulic conductivity

I = hydraulic gradient

n_e= effective porosity, the ratio of the volume of hydraulically connected pore space to total volume of geologic medium.

The flow rate was calculated to be 1.0 feet/day (0.3 meters/day) to the north. In the vicinity of Castle Ford, the rate of ground water flow toward the marsh located west of the study area was calculated to be 0.5 feet/day (0.15 meters/day). The hydraulic conductivity (K) was calculated from the average transmissivity of 60,000 gal/day/ft as determined by the 24 hour pump test (Section 4.5) and the average aquifer thickness of 23.5 feet. The effective porosity (n_e) was estimated to be 30 percent (0.30) based on the ranges of porosity values cited for sands and silts in Freeze and Cherry (1979).

4.4 Environmental Sampling

This section presents the analytical results for the ground water, soil, surface water, and stream sediment samples collected in association with conducting the RI. The data tables presenting the analytical results list only the compounds detected (i.e., Table 4-5 presents the entire Target Compound List (TCL) of volatile and semi-volatile compounds. Analytical results followed by the qualifier "B" are not discussed because the result is qualitatively questionable because the compound was detected in the travel blank and/or method blank. Quality assurance reviews of all analytical results are presented in Appendix G.

TABLE 4-5

TARGET COMPOUND LIST OF
VOLATILE AND SEMIVOLATILE COMPOUNDS

Target Compound List (TCL) and
Contract Required Quantitation Limits (CRQL)

Volatiles	CAS Number	Detection Limits* Low Water[a] ug/l	Low Soil/Sediment[b] ug/kg
1. Chloromethane	74-87-3	10	10
2. Bromomethane	74-83-9	10	10
3. Vinyl Chloride	75-01-4	10	10
4. Chloroethane	75-00-3	10	10
5. Methylene Chloride	75-09-2	5	5
6. Acetone	67-64-1	10	10
7. Carbon Disulfide	75-15-0	5	5
8. 1,1-Dichloroethene	75-35-4	5	5
9. 1,1-Dichloroethane	75-35-3	5	5
10. 1,2-Dichloroethene (total)	540-54-0	5	5
11. Chloroform	67-66-3	5	5
12. 1,2-Dichloroethane	107-06-2	5	5
13. 2-Butanone	78-93-3	10	10
14. 1,1,1-Trichloroethane	71-55-6	5	5
15. Carbon Tetrachloride	56-23-5	5	5
16. Vinyl Acetate	108-05-4	10	10
17. Bromodichloromethane	75-27-4	5	5
18. 1,1,2,2-Tetrachloroethane	79-34-5	5	5
19. 1,2-Dichloropropane	78-87-5	5	5
20. cis-1,3-Dichloropropene	10061-01-5	5	5
21. Trichloroethene	79-01-6	5	5
22. Dibromochloromethane	124-48-1	5	5
23. 1,1,2-Trichloroethane	79-00-5	5	5
24. Benzene	71-43-2	5	5
25. trans-1,3-Dichloropropene	10061-02-6	5	5

TABLE 4-5
(Continued)

Volatiles	CAS Number	Detection Limits* Low Water[a] ug/l	Low Soil/Sediment[b] ug/kg
26. Bromoform	75-25-2	5	5
27. 2-Hexanone	591-78-6	10	10
28. 4-Methyl-2-pentanone	108-10-1	10	10
29. Tetrachloroethene	127-18-4	5	5
30. Toluene	108-88-3	5	5
31. Chlorobenzene	108-90-7	5	5
32. Ethyl Benzene	100-41-4	5	5
33. Styrene	100-42-5	5	5
34. Total Xylenes	100-42-5	5	5

[a]Medium Water Contract Required Detection Limits (CRDL) for Volatile TCL Compounds are 100 times the individual Low Water CRDL.

[b]Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Volatile TCL Compounds are 100 times the individual Low Soil/Sediment CRDL.

TABLE 4-5
(Continued)

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/l	Low Soil/Sediment[d] ug/kg
35. Phenol	108-95-2	10	330
36. bis(2-Chloroethyl)ether	111-44-4	10	330
37. 2-Chlorophenol	95-57-8	10	330
38. 1,3-Dichlorobenzene	541-73-1	10	330
39. 1,4-Dichlorobenzene	106-46-7	10	330
40. Benzyl Alcohol	100-51-6	10	330
41. 1,2-Dichlorobenzene	95-50-1	10	330
42. 2-Methylphenol	95-48-7	10	330
43. bis(2-Chloroisopropyl) ether	39638-32-9	10	330
44. 4-Methylphenol	106-44-5	10	330
45. N-Nitroso-Dipropylamine	621-64-7	10	330
46. Hexachloroethane	67-72-1	10	330
47. Nitrobenzene	98-95-3	10	330
48. Isophorone	78-59-1	10	330
49. 2-Nitrophenol	88-75-5	10	330
50. 2,4-Dimethylphenol	105-67-9	10	330
51. Benzoic Acid	65-85-0	50	1600
52. bis(2-Chloroethoxy) methane	111-91-1	10	330
53. 2,4-Dichlorophenol	120-83-2	10	330
54. 1,2,4-Trichlorobenzene	120-82-1	10	330
55. Naphthalene	91-20-3	10	330
56. 4-Chloroaniline	106-47-8	10	330
57. Hexachlorobutadiene	87-68-3	10	330
58. 4-Chloro-3-methylphenol	59-50-7	10	330
59. 2-Methylnapthalene	91-57-6	10	330
60. Hexachlorocyclopentadiene	77-47-4	10	330
61. 2,4,6-Trichlorophenol	88-06-2	10	330
62. 2,4,5-Trichlorophenol	95-95-4	50	1600

TABLE 4-5
(Continued)

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/l	Low Soil/Sediment[d] ug/kg
63. 2-Chloronapthalene	91-58-7	10	330
64. 2-Nitroaniline	88-74-4	50	1600
65. Dimethyl Phthalate	131-11-3	10	330
66. Acenaphthylene	208-96-8	10	330
67. 3-Nitroaniline	99-09-2	50	1600
68. Acenaphthene	83-32-9	10	330
69. 2,4-Dinitrophenol	51-28-5	50	1600
70. 4-Nitrophenol	100-02-7	50	1600
71. Dibenzofuran	132-64-9	10	330
72. 2,4-Dinitrotoluene	121-14-2	10	330
73. 2,6-Dinitrotoluene	606-20-2	10	330
74. Diethylphthalate	84-66-2	10	330
75. 4-Chlorophenyl Phenyl ether	7005-72-3	10	330
76. Fluorene	86-73-7	10	330
77. 4-Nitroaniline	100-01-6	50	1600
78. 4,6-Dinitro-2-methylphenol	534-52-1	50	1600
79. N-nitrosodiphenylamine	86-30-6	10	330
80. 4-Bromophenyl Phenyl ether	101-55-3	10	330
81. Hexachlorobenzene	118-74-1	10	330
82. Pentachlorophenol	87-86-5	50	1600
83. Phenanthrene	85-01-8	10	330
84. Anthracene	120-12-7	10	330
85. Di-n-butylphthalate	84-74-2	10	330
86. Fluoranthene	206-44-0	10	330
87. Pyrene	129-00-0	10	330
88. Butyl Benzyl Phthalate	85-68-7	10	330
89. 3,3'-Dichlorobenzidine	91-94-1	20	660
90. Benzo(a)anthracene	56-55-3	10	330
91. bis(2-ethylhexyl)phthalate	117-81-7	10	330

TABLE 4-5
(Continued)

Semi-Volatiles	CAS Number	Detection Limits* Low Water[c] ug/l	Low Soil/Sediment[d] ug/kg
92. Chrysene	218-01-9	10	330
93. Di-n-octyl Phthalate	117-84-0	10	330
94. Benzo(b)fluoranthene	205-99-2	10	330
95. Benzo(k)fluoranthene	207-08-9	10	330
96. Benzo(a)pyrene	50-32-8	10	330
97. Indeno(1,2,3-cd)pyrene	193-39-5	10	330
98. Dibenz (a,h)anthracene	53-70-3	10	330
99. Benzo(g,h,i)perylene	191-24-2	10	330

[c]Medium Water Contract Required Detection Limits (CRDL) for Semi-Volatile TCL Compounds are 100 times the individual Low Water CRDL.

[d]Medium Soil/Sediment Contract Required Detection Limits (CRDL) for Semi-Volatile TCL Compounds are 60 times the individual Low Soil/Sediment CRDL.

4.4.1 Ground Water Quality

The concentrations of Target Compound List (TCL) volatile and semi-volatile compounds identified in ground water samples collected from monitoring wells on both the New Castle Spill Site and the NCBW&L properties are presented in Table 4-6 and on Plate 1. Trichloroethene (TCE) and tris were the most commonly identified TCL volatile and semi-volatile compounds in the 17 wells sampled.

Volatile Organic Compounds

TCE was detected in 8 of the 17 wells sampled. Figure 4-9 shows well locations and the distribution of TCE detected in ground water samples collected during April 1988. Concentrations ranged from a quantitative estimate of 1 ug/l in well OB-3, to a high of 120 ug/l in well OB-1 located behind Castle Ford. The levels of TCE generally declined moving from south to north (i.e., upgradient to downgradient) toward the New Castle Spill Site; 120 ug/l in well OB-1, 93 ug/l in well MW-3, followed by 66 ug/l in well MW-5, and 8 ug/l in well MW-2. The highest concentrations of TCE in ground water occurred in wells located upgradient of the recognized spill source area. This distribution of TCE in ground water is considered to represent an upgradient source area for this compound.

In addition to TCE, only two other volatile compounds were identified in the ground water samples. One of these compounds, 1,2-dichloroethene, was detected in wells OB-1 and MW-3 at concentrations of 11 and 5 ug/l, respectively. This compound is a common degradation by-product of TCE. In addition to 1,2-dichloroethene, carbon disulfide was detected at 15 ug/l in well OB-28. This compound was not detected in any of the other

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Figure 4-9
Concentration of Trichloroethene in the Water Table Aquifer (µg/l), 18 April 1988
New Castle Spill Site

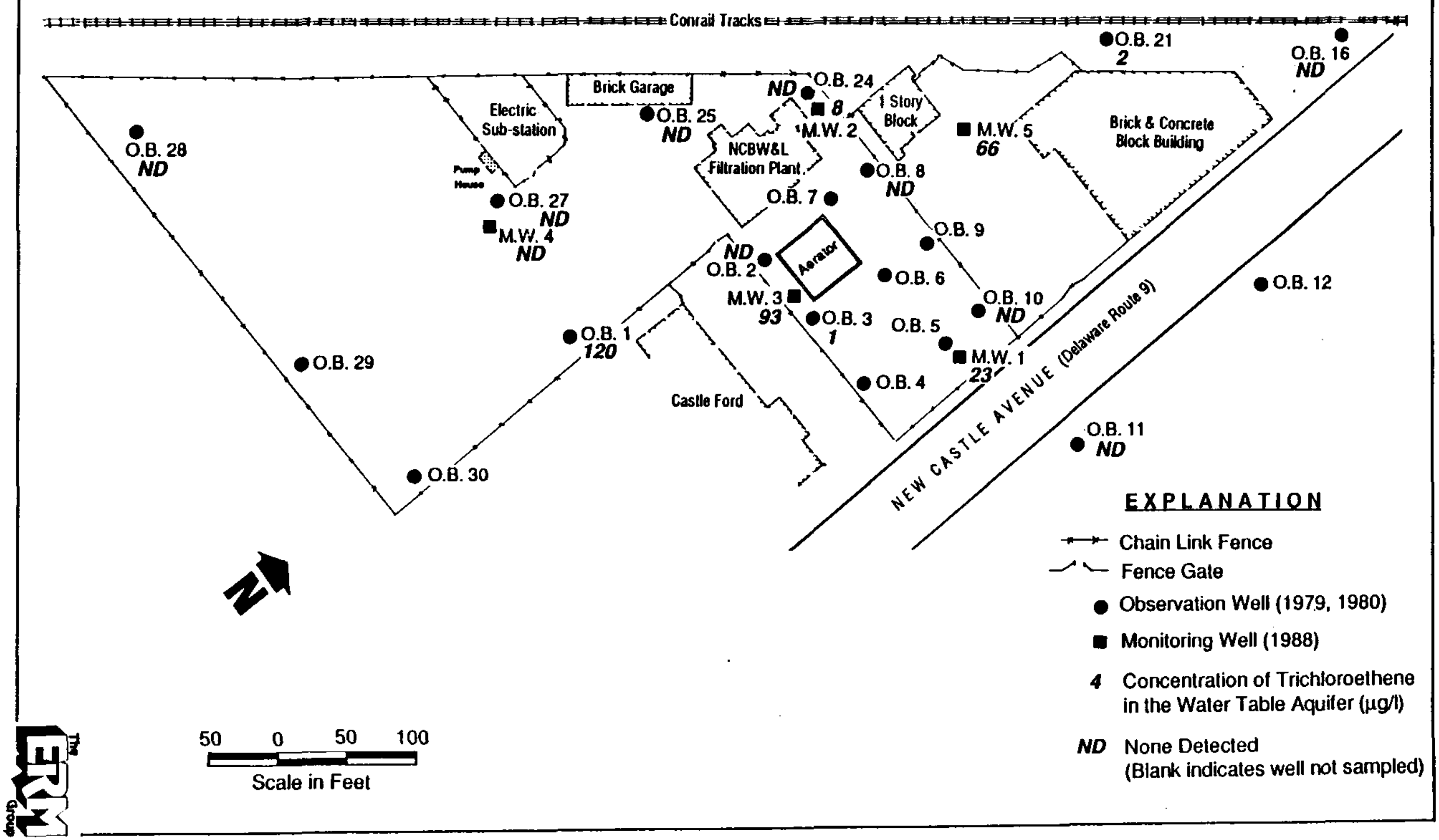

Table 4-6
Analytical Results For Ground Water Samples
New Castle Spill Site

ERM T. R. No. Sample Location Sample Date Units	7805 MW-1 4/19/88 ug/l	7812 MW-2 4/20/88 ug/l	7799 MW-3 4/18/88 ug/l	7798 MW-4 4/18/88 ug/l	7800 MW-5 4/18/88 ug/l	7803 OB-1 4/19/88 ug/l
Volatile Organics						
Methylene Chloride	2 B					2 B
Acetone	1 B					
Carbon Disulfide						
1,2-Dichloroethene (total)			5			11
2-Butanone						
Trichloroethene	23	8	93		66	120
4-Methyl-2-Pentanone						
2-Hexanone						
Toluene						
Tetrachloroethene						
Tentatively Indentified Volatile Compounds						
Dichlorofluoromethane						
Trichlorofluoromethane					18 J	
total unknowns				5 J		
Semi Volatiles						
naphthalene						
2-methylnaphthalene						
fluorene						
bis(chloroisopropyl)ether						
1,2-Dichlorobenzene				2 J		
Diethylphthalate		5 B	6 B*	8 B*	4 B*	
Bis(2-Ethylhexyl)Phthalate		19 B	12 B*	4 B*	6 B*	3 B
Tentatively Indentified Semi Volatile Compounds						
hexadecanoic acid						
2-Butoxy-Ethanol				440 J		
5-methyl-2-hexanone						
total dimethyl napthalene isomers						
total unknowns		40 J	24 J	2276 J	114 J*	16 J
Additional Semi Volatiles						
Tris(2-chloropropyl) Phosphate		12.6 B		17.1 *	2.4 B*	
Inorganics						
Iron	3900 E	357 B	15900 E	843 E	719 E	18800 E
Manganese	2100 E	456 E	4820 E	5230 E	1060 E	635 E
COD	9700	6000	6000	19000	68000	42000
TOC	1400	1300	940	1500	1300	4400

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"E" - The associated ICP serial dilution analysis exceeded the allowable 10% difference from the undiluted analysis.
"*" - This result is from a reextraction analysis.
"**" - Value reported from dilution analysis to allow accurate quantitation.

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Table 4-6
Analytical Results For Ground Water Samples
New Castle Spill Site

ERM T. R. No. Sample Location Sample Date Units	7804 OB-2 4/19/88 ug/l	7806 OB-3 4/19/88 ug/l	7815 OB-8 4/21/88 ug/l	7810 OB-10 4/20/88 ug/l	7813 OB-11 4/20/88 ug/l	7817 OB-16 4/21/88 ug/l
Volatile Organics						
Methylene Chloride	2 B	4 B			8 B	
Acetone		1 B		3 B	5 B	
Carbon Disulfide						
1,2-Dichloroethene (total)						
2-Butanone						
Trichloroethene		1 J				
4-Methyl-2-Pentanone						
2-Hexanone						
Toluene						
Tetrachloroethene		1 B				
Tentatively Indentified Volatile Compounds						
Dichlorofluoromethane			29 J			
Trichlorofluoromethane			950 J			13 J
total unknowns			17 J			
Semi Volatiles						
naphthalene			8 J			
2-methylnaphthalene			5 J			
fluorene			2 J			
bis(chloroisopropyl)ether						
1,2-Dichlorobenzene						
Diethylphthalate			4 B			4 B
Bis(2-Ethylhexyl)Phthalate	4 B	3 B	7 B	15 B	3 B	6 B
Tentatively Indentified Semi Volatile Compounds						
hexadecanoic acid		10 J				
2-Butoxy-Ethanol						
5-methyl-2-hexanone						
total dimethyl napthalene isomers			24 J			
total unknowns	44 J		198 J	28 J		48 J
Additional Semi Volatiles						
Tris(2-chloropropyl) Phosphate			2160 **	179		51.4
Inorganics						
Iron	293 B	19400 J	4600 E	39 B	39 B	100 B
Manganese	5240 E	1060 E	1630 E	65 E	81 E	26 E
COD	25000	32000	60000	21000	31000	87000
TOC	3200	6600	15000	4600	3600	2200

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"E" - The associated ICP serial dilution analysis exceeded the allowable 10% difference from the undiluted analysis.
"**" - This result is from a reextraction analysis.
"***" - Value reported from dilution analysis to allow accurate quantitation.

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Table 4-6
Analytical Results For Ground Water Samples
New Castle Spill Site

ERM T. R. No. Sample Location Sample Date Units	7816 OB-21 4/21/88 ug/l	7811 OB-24 4/20/88 ug/l	7809 OB-25 4/20/88 ug/l	7808 OB-27 4/20/88 ug/l	7802 OB-28 4/19/88 ug/l
Volatile Organics					
Methylene Chloride	41 B		2 B		3 B
Acetone	15 B				6 B
Carbon Disulfide					15
1,2-Dichloroethene (total)					
2-Butanone					2 B
Trichloroethene	2 J				
4-Methyl-2-Pentanone					2 B
2-Hexanone					2 B
Toluene	3 B				
Tetrachloroethene					2 B
Tentatively Indentified Volatile Compounds					
Dichlorofluoromethane	3 J				
Trichlorofluoromethane	50 J				
total unknowns					
Semi Volatiles					
naphthalene	8 J				
2-methylnaphthalene					
fluorene					
bis(chloroisopropyl)ether	6 J				
1,2-Dichlorobenzene					
Diethylphthalate	6 B				
Bis(2-Ethylhexyl)Phthalate	7 B	20 B	17 B	9 B	7 B
Tentatively Indentified Semi Volatile Compounds					
hexadecanoic acid					
2-Butoxy-Ethanol					
5-methyl-2-hexanone		14 J			
total dimethyl napthalene isomers					
total unknowns	474 J	84 J	26 J	10 J	
Additional Semi Volatiles					
Tris(2-chloropropyl) Phosphate	74600 **	188	66.6		6.14 B
Inorganics					
Iron	111 B	13000 E	27 B	34 B	432 B
Manganese	1780 E	1150 E			62 E
COD	280000	14000	110000	9700	12000
TOC	130000	3500	3100	1300	2500

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"E" - The associated ICP serial dilution analysis exceeded the allowable 10% difference from the undiluted analysis.
"*" - This result is from a reextraction analysis.
"**" - Value reported from dilution analysis to allow accurate quantitation.

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16 wells and its presence in well OB-28 also suggests an upgradient source.

Tentatively identified compounds included trichlorofluoromethane and dichlorofluoromethane. Trichlorofluoromethane was detected in four wells located both within the recognized spill source area and in a downgradient direction. This compound had the highest estimated concentration of 950 ug/l in well OB-8 and an estimated concentration of 50 ug/l in well OB-21. This compound was also detected in wells MW-5 and OB-16 at estimated concentrations of 18 and 13 ug/l, respectively. The occurrence and distribution of trichlorofluoromethane is consistent with that defined by previous samplings. In addition to trichlorofluromethane, dichlorofluoromethane was detected in wells OB-8 and OB-21 at estimated concentrations of 29 and 3 ug/l, respectively. These compounds are a related class of freons.

In addition to the aforementioned compounds, unknown compounds were identified in both wells OB-8 and MW-4. These unknown compounds have estimated concentrations of 17 and 5 ug/l, respectively.

Semi-Volatile Organic Compounds

Tris was detected in 7 of 17 ground water samples collected. The highest concentration of tris was in well OB-21 (74,600 ug/l) located along the Conrail tracks on the northwest side of the New Castle Spill Site. Well OB-8, located within the recognized spill source area, had the second highest tris concentration of 2,160 ug/l. Tris levels detected in wells OB-24 and OB-10 were 188 and 179 ug/l, respectively. Tris concentrations were less than 100 ug/l in wells OB-25, OB-16, and MW-4. Generally, the tris levels were higher in the "OB" wells which are screened from approximately 7.5 to 12.5 feet below land surface (BLS) than in the "MW" wells, which are screened from approximately 23 to 28 feet BLS. Figures 4-10 and 4-11 show the distribution of tris detected in ground water samples collected April 1988 from OB and MW wells, respectively. All wells within the study area were checked with an interface probe for signs of either a sinking or floating product; no evidence of a product was observed.

Semi-volatile compounds, including naphthalene, 2-methyl naphthalene, fluorene, and bis(chloroisoproply) ether, were qualitatively detected in ground water samples collected from wells within the spill source area and downgradient. In addition, 1,2-dichlorobenzene was qualitatively detected upgradient in well MW-4.

Generally, unknown semi-volatile compounds were present in all wells, with the exception of wells OB-28, MW-1, and OB-11. The highest concentrations of unknowns were detected in well MW-4 (2,276 ug/l) and well OB-8 (1,208 ug/l).

Analysis Conducted to Assist in Evaluation of Remedial Alternatives

Ground water samples were tested for total organic carbon (TOC), chemical oxygen demand (COD), iron, and manganese to aid in the evaluation of remedial alternatives. These results are included in Table 4-6. Samples collected for iron and manganese analyses were filtered to characterize the dissolved concentrations.

Levels of COD detected in ground water ranged from 6 mg/l to 110 mg/l. TOC values ranged from 940 ug/l to 130,000 ug/l. The ground water sample collected from upgradient (background) well OB-28 had a COD value of 12 mg/l and TOC concentration of 2,500 ug/l. Generally, the COD and TOC levels increased as the

31006 01

Figure 4-10
Concentration of Tris(2-Chloropropyl) Phosphate in the OB Series Wells (µg/l), 18 April 1988
New Castle Spill Site

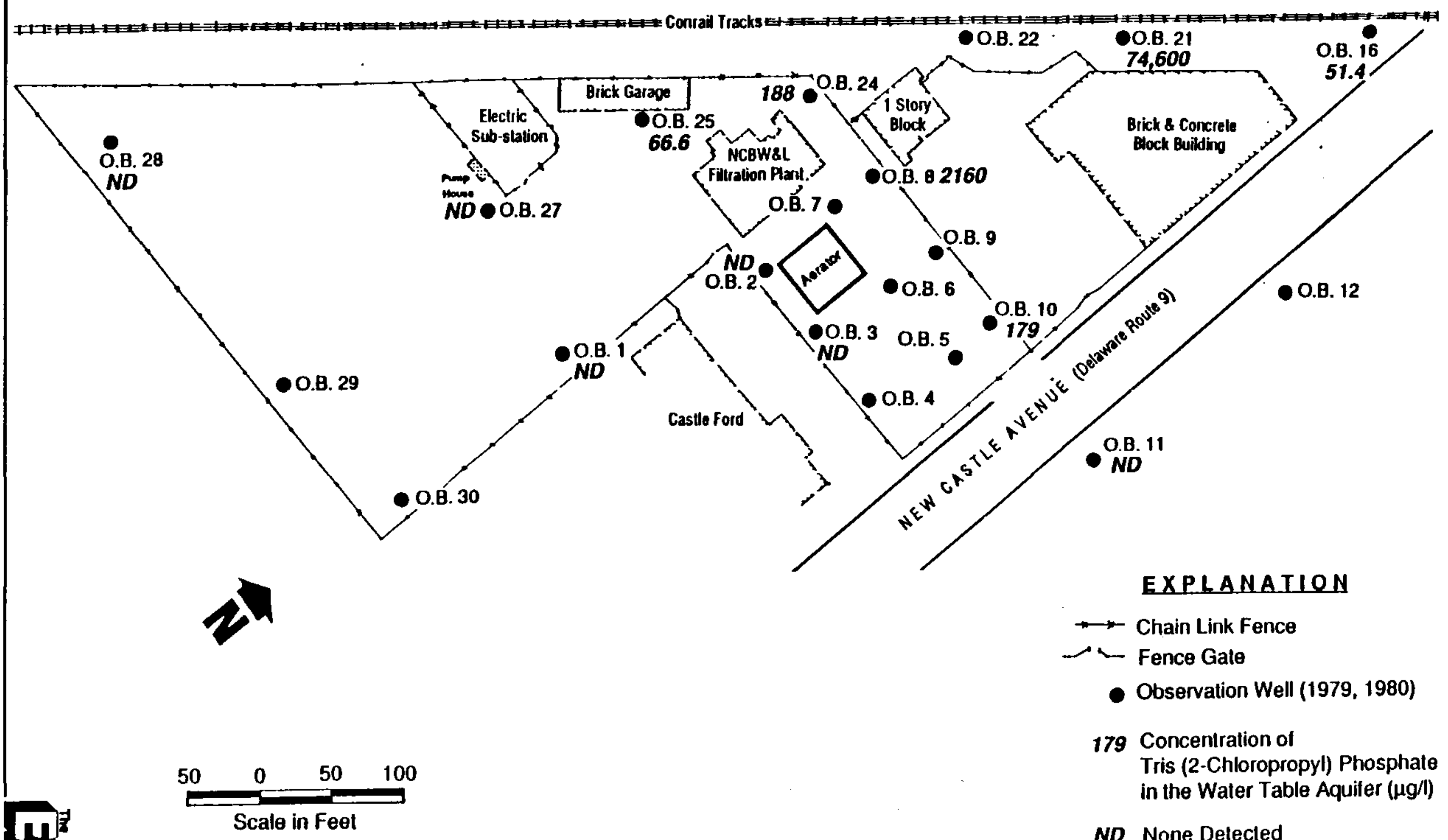

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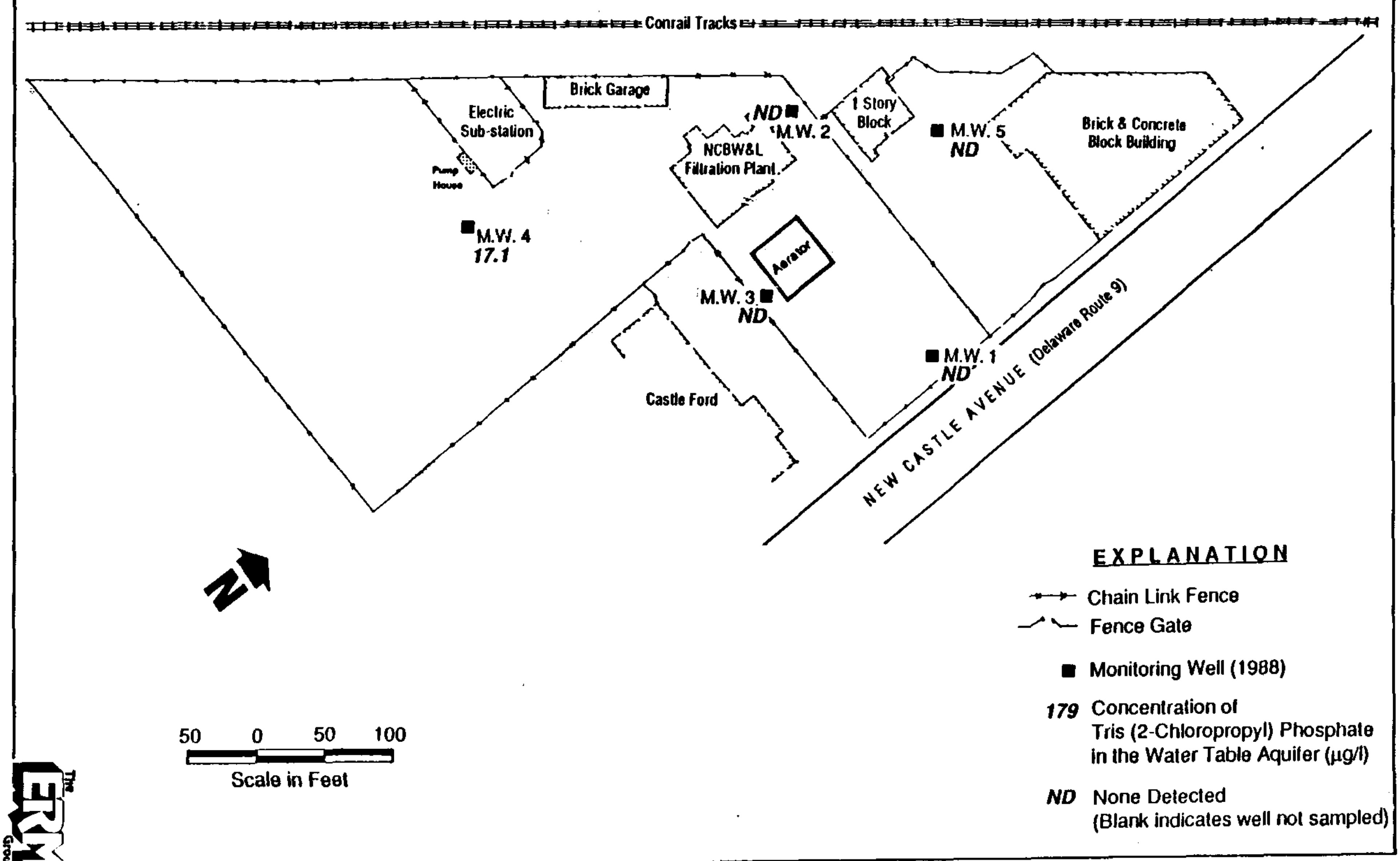
Figure 4-11
Concentration of Tris(2-Chloropropyl) Phosphate in the MW Series Wells (µg/l), 18 April 1988
New Castle Spill Site



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concentration of organic compounds increased. The highest levels of COD and TOC were observed in wells OB-8 (60,000 and 15,000 ug/l respectively) and OB-21 (280,000 and 130,000 ug/l respectively) which also contained the highest levels of tris.

The concentrations of iron and manganese reported for many samples are flagged with an "E" qualifier as required by the Contracts Laboratory Program (CLP) protocol. This designation was assigned when samples from wells OB-3 and MW-2 underwent a serial dilution analysis and the results were not within 10 percent of the original analysis (Appendix G). CLP protocol requires that all data generated from analysis conducted during the testing of samples from wells OB-3 and MW-2 be qualified. It is ERM's opinion that only the results from wells OB-3 and MW-2 should be discussed as estimated values. For purposes of this discussion, all other iron and manganese data qualified with an "E" will be considered quantitatively confirmed.

Water from the Columbia aquifer is generally slightly acidic and high in iron and manganese. Sundstrom et al., (1975) reported that combined iron and manganese concentrations range from 0.02 to 21.0 mg/l. Iron and manganese levels detected in ground water samples exceeded this range only in well OB-24. Primary Drinking Water Standards do not exist for iron and manganese. Ambient water quality criteria under the Clean Water Act specifies maximum levels of 0.3 mg/l of iron and 0.50 mg/l of manganese for drinking water. Iron and manganese levels detected in the ground water samples collected during this study indicate that consideration would have to be given to treatment of the water to make it suitable for drinking water.

Field pH, Specific Conductance, and Temperature

Field pH, specific conductance, and temperature measurements for ground water samples from all wells are presented in Table 4-7. Specific conductance varied from 100 to 600 umhos/cm, with a mean value of 277 umhos/cm. Temperature values ranged from 10 to 14°C. Ground water pH levels ranged from 5.4 to 6.7 and were within the background range for pH.

4.4.2 Soils

The concentrations of TCL volatile and semi-volatile compounds compounds detected in soils collected from both the New Castle Spill Site and NCBW&L properties are given in Table 4-8 and on Plate 2. The two volatile compounds detected in greatest concentration in the soils were 2-butanone and trichlorofluoromethane. However, only 2-butanone and not trichlorofluoromethane was quantitatively identified. Several semi-volatile compounds were detected in the soils, including tris, which was detected in 9 of 15 soil samples.

Volatile Organic Compounds

Two compounds, ethylbenzene and 2-butanone, were quantitatively identified during the soil sampling program. Both compounds were detected in boring B-2, located along the Conrail tracks, from samples collected in the 2- to 4-foot and 4- to 6.5-foot BLS sampling intervals. Ethylbenzene was detected in the 2- to 4-foot BLS sample at a concentration of 11 ug/kg while 2-butanone was detected at a concentration of 47 ug/kg in the 4- to 6.5-foot sampling interval.

Table 4-7
Field Measurements of Specific Conductance, Temperature and pH
on Ground Water Samples
New Castle Spill Site

Well	pH	Specific Conductance (μmhos/cm)	Temperature (°C)
MW - 1	5.7	350	12
MW - 2	5.9	200	12
MW - 3	5.5	400	13
MW - 4	6	600	12
MW - 5	5.7	340	14
OB - 1	6.4	300	12
OB - 2	6.2	300	10
OB - 3	6.4	350	10
OB - 8	6.1	200	10
OB - 10	6.2	175	10
OB - 11	6	100	10
OB - 16	6.2	380	11
OB - 21	6.6	215	11
OB - 24	6.7	300	12
OB - 25	6.7	300	11
OB - 27	5.7	100	10
OB - 28	5.4	100	10

Table 4-8
Analytical Results For Soil Samples
New Castle Spill Site
All results are reported in units of ug/kg on a dry weight basis

ERM T. R. No. Sample Location Sample Date Units	6605 B-1,(6-8') 3/7/88 ug/kg	6869 B-2(2-4') 3/18/88 ug/kg	6870 B-2(4-6.5') 3/18/88 ug/kg	6867 B-3(0-2') 3/18/88 ug/kg	6607 MW-1(0-2') 3/8/88 ug/kg	6608 MW-1(2-4') 3/8/88 ug/kg
Volatile Organics						
Methylene Chloride	9 B	12 B	6 B	16 B	11 B	15 B
Acetone		110 B	51 B	18 B		
Carbon Disulfide						
2-Butanone		11 B	47			
Toluene						
Ethylbenzene		11				
Total Xylenes		25 B				
Tentatively Indentified Volatile Compounds						
Trichlorofluoromethane						
Methoxyethene						
Acetaldehyde		72 J	42 J			
Trimethyl-Silanol		16 J				
Total Unknowns						
Semi Volatiles						
Naphthalene						
Acenaphthene						
Isophorone		79 J				
2-Methyl Naphthalene						
Dibenzofuran						
Fluorene						
Phenanthrene					58 J	
Diethylphthalate						
Di-n-Butylphthalate						
Fluoranthene					220 J	
Anthracene						
Pyrene				44 J	130 J	
Benzo(a) Anthracene					83 J	
Chrysene					130 J	
Bis(2-Ethylhexyl)Phthalate					51 B	40 B
Benzo(b) Fluoranthene (1)					200 J	
Benzo(a) Pyrene					94 J	
Indeno(1,2,3-cd) Pyrene					100 J	
Tentatively Indentified Semi Volatile Compounds						
5-Ethyl-2-Methyl-Octane						
Octadecanal					1400 J	340 J
1,3,5 -Cycloheptatriene						
Unknown Alkyl Benzene		550 J				
Unknown Acid					400 J	
Total Unknown Alkane					1560 J	
Total Unknowns		3550 J	3530 J		2840 J	
Additional Semi Volatiles						
Tris(2-chloropropyl) Phosphate		54 J	55 J	500		
Acidity-EPA 305.1 (ug/g as $CaCO_3$)	60	240	141	440	480	<24
Specific Gravity (g/ml)	2.62	2.58	2.63	2.51	2.72	2.78

Qualifiers:
"B" - This result is qualitatively questionable becasue the compound was detected in method and/or travel blanks at similar concentrations
"J" - This result is an estimated concentration.
Blank spaces - indicate the compound was not detected.
(1)- Benzo(b)fluoranthene and benzo(k)fluoranthene are not resolved by the analytical method. Concentrations represent the total of both isomers.

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Table 4-8
Analytical Results For Soil Samples
New Castle Spill Site
All results are reported in units of ug/kg on a dry weight basis

ERM T. R. No. Sample Location Sample Date Units	6610 MW-2(2-4') 3/9/88 ug/kg	6611 MW-3(4-6') 3/10/88 ug/kg	6614 MW-4(2-4') 3/11/88 ug/kg	6612 MW-4(6-8') 3/11/88 ug/kg	6615 MW-5(2-4') 3/14/88 ug/kg	6616 MW-5(4-6') 3/14/88 ug/kg
Volatile Organics						
Methylene Chloride	7 B	14 B	11 B	14 B	78 B	8 B
Acetone					200 B	59 B
Carbon Disulfide					6 J	
2-Butanone						
Toluene						2 B
Ethylbenzene						
Total Xylenes						
Tentatively Indentified Volatile Compounds						
Trichlorofluoromethane					180 J	670 J
Methoxyethene						
Acetaldehyde						
Trimethyl-Silanol						
Total Unknowns					63 J	24 J
Semi Volatiles						
Naphthalene					390 J	
Acenaphthene					580 J	
Isophorone						
2-Methyl Naphthalene						
Dibenzofuran					470 J	
Fluorene					580 J	
Phenanthrene	270 J				4400 J	120 J
Diethylphthalate	92 B	50 B	39 B	54 B		
Di-n-Butylphthalate						
Fluoranthene	380 J				3600 J	160 J
Anthracene	51 J				1100 J	
Pyrene	190 J				2400 J	130 J
Benzo(a) Anthracene	140 J				1300 J	60 J
Chrysene	140 J				1800 J	65 J
Bis(2-Ethylhexyl)Phthalate				38 J		
Benzo(b) Fluoranthene (1)	230 J				2500 J	99 J
Benzo(a) Pyrene	91 J				1200 J	
Indeno(1,2,3-cd) Pyrene						
Tentatively Indentified Semi Volatile Compounds						
5-Ethyl-2-Methyl-Octane						
Octadecanal						
1,3,5 -Cycloheptatriene						
Unknown Alkyl Benzene						
Unknown Acid						
Total Unknown Alkane						
Total Unknowns	950 J	2200 J		1600 J		1220 J
Additional Semi Volatiles						
Tris(2-chloropropyl) Phosphate	336 J				11740 J	3600 J
Acidity-EPA 305.1 (ug/g as CaCO3)	<25	98	87	47	<22	<22
Specific Gravity (g/ml)	2.65	2.6	2.8	2.65	2.51	2.67

Qualifiers:
"B" - This result is qualitatively questionable becasue the compound was detected in method and/or travel blanks at similar concentrations
"J" - This result is an estimated concentration.
Blank spaces - indicate the compound was not detected.
(1)- Benzo(b)fluoranthene and benzo(k)fluoranthene are not resolved by the analytical method. Concentrations represent the total of both isomers.

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Table 4-8
Analytical Results For Soil Samples
New Castle Spill Site
All results are reported in units of ug/kg on a dry weight basis

ERM T. R. No.	6617	6619	6620
Sample Location	MW-5(6-8')	PW-1(0-2')	PW-1(2-4')
Sample Date	3/14/88	3/16/88	3/16/88
Units	ug/kg	ug/kg	ug/kg
Volatile Organics			
Methylene Chloride	6 B	20 B	13 B
Acetone			11 B
Carbon Disulfide			
2-Butanone			2 B
Toluene			
Ethylbenzene			
Total Xylenes			
Tentatively Indentified Volatile Compounds			
Trichlorofluoromethane			
Methoxyethene			
Acetaldehyde			
Trimethyl-Silanol			
Total Unknowns			
Semi Volatiles			
Naphthalene			
Acenaphthene			
Isophorone			
2-Methyl Naphthalene		42 J	
Dibenzofuran			
Fluorene			
Phenanthrene	110 J	95 J	
Diethylphthalate			
Di-n-Butylphthalate		410 B	77 B
Fluoranthene	130 J	140 J	53 J
Anthracene			
Pyrene	98 J	110 J	39 J
Benzo(a) Anthracene	41 J	61 J	
Chrysene	55 J	140 J	47 J
Bis(2-Ethylhexyl)Phthalate		190 B	44 B
Benzo(b) Fluoranthene (1)		190 J	87 J
Benzo(a) Pyrene			
Indeno(1,2,3-cd) Pyrene			
Tentatively Indentified Semi Volatile Compounds			
5-Ethyl-2-Methyl-Octane		480 J	
Octadecanal			
1,3,5 -Cycloheptatriene			
Unknown Alkyl Benzene			
Unknown Acid			
Total Unknown Alkane			
Total Unknowns	300 J		8000 J
Additional Semi Volatiles			
Tris(2-chloropropyl) Phosphate	1960 J	2630 J	3770 J
Acidity-EPA 305.1 (ug/g as $CaCO_3$)	<22	580	340
Specific Gravity (g/ml)	2.6	1.77	2.69

Qualifiers:
"B" - This result is qualitatively questionable becasue the compound was detected in method and/or travel blanks at similar concentrations
"J" - This result is an estimated concentration.
Blank spaces - indicate the compound was not detected.
(1)- Benzo(b)fluoranthene and benzo(k)fluoranthene are not resolved by the analytical method. Concentrations represent the total of both isomers.

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Three compounds, trichlorofluoromethane, acetaldehyde, and trimethyl-silanol, were tentatively identified in the soils analyses. Trichlorofluoromethane was detected only in soil samples collected during the drilling of well MW-5, located within the recognized source area at the New Castle Spill Site. The other two compounds were detected in boring B-2, with acetaldehyde present in both sampling intervals and trimethyl-silanol present in only the 2- to 4-foot BLS sample interval. In addition to these tentatively identified volatile compounds, volatile unknowns were present only in soil samples collected from well MW-5.

TCE was not detected in any soil samples collected during the RI investigation. Soil samples collected during the drilling of well PW-1 installed in the source area by ERM to serve as a recovery well did not detect TCE at the 0- to 2-foot and 2- to 4-foot sample intervals. Well MW-5 is centrally located on the former plant site and soil samples collected at 2-foot intervals from land surface to a depth of 8-feet did not detect TCE. Earlier discussions of groundwater quality indicated that TCE was detected in a groundwater sample from well MW-5 at 66 ug/l. The absence of TCE in soil samples collected from this well indicates that the occurrence of TCE in the groundwater is not the result of a surface spill but probably related to groundwater contamination coming from an upgradient source.

Semi-Volatile Organic Compounds

Tris was detected in 9 of 15 soil samples collected in the vicinity of the recognized spill source area. The highest concentration was found in the 2- to 4-foot sample collected from well MW-5. Within this boring, the soil concentration of Tris decreased from 11,740 ug/kg, in the 2- to 4-foot interval, to 3,600 ug/kg in the 4- to 6-foot interval. Tris concentrations continued to decrease with depth down to 1,960 ug/kg in the 6- to 8-foot interval. Elevated concentrations of tris were also detected from 0 to 4 feet in the 2 samples analyzed from well PW-1. Samples from well MW-2 (2 to 4 feet) and B-3 (0 to 2 feet) had respective concentrations of 336 and 491 ug/kg. Both samples from boring B-2 had estimated tris concentrations of approximately 55 ug/kg.

The distribution of tris in the samples collected during the soils investigation reflects high concentrations in those samples collected on site and from within the recognized spill source area (MW-5 and PW-1). Elevated concentrations detected in the vicinity of well MW-2 and boring B-3 reflect a probable redistribution of tris via surface drainage through the spill source area and along these drainage pathways.

Additional TCL semi-volatile compounds, primarily polynuclear aromatic hydrocarbons (PAHs), were detected in the soil sampling program. These compounds were detected primarily in samples collected during the drilling of wells MW-1, MW-2, MW-5, and PW-1. Phenanthrene, fluoranthene, benzo(b)fluoranthene, and pyrene were the predominant PAHs in the soil samples collected. With exception of MW-1, the soil samples collected during the drilling of wells MW-5 and PW-1 show an order of magnitude decrease in PAH concentration between the shallowest sample and the next sample immediately beneath it. For example, phenanthrene was quantitatively confirmed at a concentration of 4,400 ug/kg in the 2- to 4-foot sample collected from MW-5. This same compound, in the 4- to 6-foot sample, had an estimated concentration of 120 ug/kg. Several PAHs were also detected in the shallow sample from MW-1 (0- to 2-feet) but were undetected in the 2- to 4-foot sample from this same boring. In general, these compounds are strongly adsorbed to organic matter and soil particles and their movement is retarded. However, they may be readily transported by surface runoff during high rainfall events.

Tentatively identified semi-volatile compounds include octadecanal in MW-1 and 5-ethyl-2-methyl-octane in PW-1. In addition to these two compounds, an unknown acid and an unknown alkane were detected in the shallow sample from MW-1. Unknown alkyl benzene was detected in boring B-2.

Total semi-volatile unknowns were detected in each soil sample and range from an estimated concentration of 32,510 ug/kg in MW-4 (6 to 8 feet) to 430 ug/kg in B-1 (6 to 8 feet). In general, the concentration of the unknowns is highest in the spill source area and in those samples collected from MW-4.

Vertical Permeability Testing

Vertical permeability tests were conducted on Shelby tube samples obtained from the clay underlying the Columbia aquifer within the study area. Permeability testing was conducted via a constant volume, variable head permeability test published by the Corps of Engineers, 1970 (refer to Appendix H).

Results of the permeability test on the five samples ranged from 1.46×10^{-8} cm/sec in MW-1 to 4.83×10^{-8} cm/sec in MW-5. The average permeability was 2.87×10^{-8} cm/sec. All hydraulic conductivity results were consistently low and reflect the nearly impermeable nature of the clay unit underlying the Columbia aquifer. Table 4-9 presents the results of the permeability tests conducted on clay samples obtained from MW-1, MW-3, MW-4, MW-5, and PW-1.

Table 4-9
Results of Vertical Permeability Testing of the Clay Unit
Potomac Formation
New Castle Spill Site

Well	Depth Range*	K ** (cm/sec)
MW-1	36.0-38.0	1.46 x 10**-8
PW-1	30.0-32.0	1.68 x 10**-8
MW-3	33.5-35.5	4.57 x 10**-8
MW-4	39.5-41.5	1.79 x 10**-8
MW-5	37.5-39.5	4.83 x 10**-8

* given in feet below land surface
* * Coefficient of permeability corrected to 20ºC

An additional task was undertaken to calculate the rate of vertical flow from the Columbia aquifer, through the clay layer, and into the underlying Potomac aquifer. This calculation is based on the equation presented in Section 4.3 where:

$$V = \frac{Ki}{n_e}$$

In this exercise, water level data obtained during the tidal fluctuation study from well OB-27, in the Columbia aquifer, and well PH, in the upper Potomac aquifer, were used to determine a vertical hydraulic gradient across the confining clay unit. By taking this head differential (5.7 ft) and dividing by the vertical separation of the two wells (85 ft), a vertical hydraulic gradient of 0.07 was found to exist between the two aquifers. Additionally, the effective porosity (n_e) of 33 percent for clays given by Fetter (1980) was used to add conservatism to the calculation, and 2.87 x 10^{-8} cm/sec was used as the final variable; K.

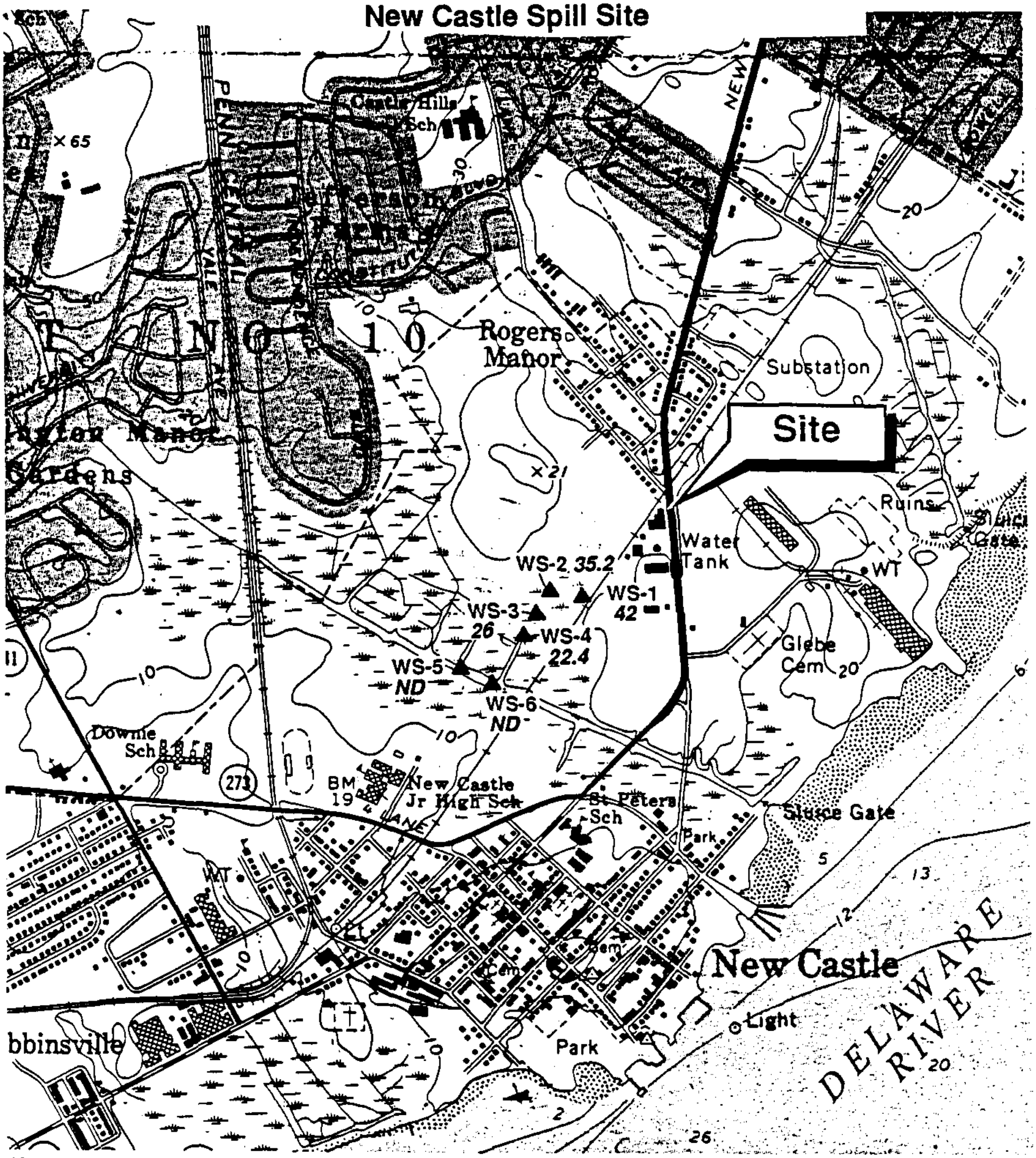
Under static conditions, the vertical migration of ground water and/or contaminants across the confining clay layer within the study area is 1.7 x 10^{-5} ft/day (6.3 x 10^{-3} ft/year). Based on this vertical flow rate it would take approximately 160 years for groundwater and/or contaminants to migrate, from the Columbia aquifer into the confining clay of the Potomac, to a depth of one-foot into the clay. An additional conservative calculation was performed which assumed a head differential of 100 feet between the Columbia and Potomac aquifers (i.e., i = 1.2). This calculation was conducted to address concerns of contaminant migration under pumping conditions if well PW-11 were returned on-line. Under these conditions, the vertical flow rate across the confining clay layer is 2.9 x 10^{-4} ft/day. Based on this vertical flow rate, it would take approximately 10 years for contaminants to migrate 1-foot into the confining clay.

4.4.3 Wetlands Sampling

Six sampling stations were established and surface water (WS) and sediment (SD) samples collected for chemical analyses. The locations of the sampling stations and concentrations of tris detected are presented in Figure 4-12. Station WS-5 is located upstream of the discharge coming from the New Castle Spill Site study area and is considered representative of background conditions. Four of the six surface water samples submitted for tris analysis had detectable concentrations of tris (Table 4-10). Concentrations ranged from 42 ug/l to 22.4 ug/l. The highest concentration was detected in sample WS-1, located closest to the New Castle Spill Site. The lowest detectable concentration was in sample WS-4, which was located farthest downstream from the New Castle Spill Site. None detectable levels of tris were observed in two surface water samples, one collected upstream (WS-5) and the second (WS-6) directly across from where the drainage enters the main channel. None detectable levels of tris were observed in all six of the sediment samples.

The range of pH values for ground water from the Columbia sediments reported by Johnston (1973) is 5.4 to 7.5. Surface water pH values ranged from 6.3 to 7.4 and specific conductance ranged from 170 to 204 umhos/cm. At sampling location WS-5 (upstream station) pH and specific conductance levels were 7.4 and 193 umhos/cm respectively. Temperature values ranged from 10°C to 14°C. Sediment pH values were neutral and ranged from 7.0 to 7.1.

Figure 4-12
Concentration of Tris (2-Chloropropyl) Phosphate in Surface Water (μg/l)
14 March 1988
New Castle Spill Site



Key:

▲ Sample Station

ND None Detected

N

Scale in Feet

0 1500 3000

Source: USGS 7.5 Min. Topographic Quadrangle; Wilmington South, DE

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Table 4-10
Analytical Results of Surface Water and Sediment Samples
New Castle Spill Site

Sample Location	Surface Water			Tris
	pH	Specific Conductance (umhos/cm)	Temperature (Celcius)	
WS - 1	7.3	195	14	42 ug/l
SD - 1				ND
WS - 2	7.3	185	14	35.2 ug/l
SD - 2				ND
WS - 3	7.1	180	14	26 ug/l
SD - 3				ND
WS - 4	6.3	170	10	22.4 ug/l
SD - 4				ND
WS - 5	7.4	193	10	ND
SD - 5				ND
WS - 6	7.1	204	10	ND
SD - 6				ND

ND Indicates None Detected
WS Designates surface water sample
SD Designates sediment sample

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Sediment samples for particle size analyses were collected from each of the six sampling stations; however, only samples GS-1, GS-5, and GS-6 were submitted for analysis. The remaining three samples contained too much humus and vegetation to be tested. These samples are described as organic fine sandy clayey silt and organic clayey silts under the Unified Soil Classification system in accordance with ASTM D422. Table 4-11 gives the particle size distribution of the three samples submitted for analysis.

4.4.4 Additional Sampling

Additional sampling of soil and ground water was conducted on 22 June 1988. These samples were collected in addition to the sampling plan approved by the DNREC. Additional sampling was conducted as a means of filling data gaps identified from the April 1988 sampling. The additional samples collected and the rationale for each sample is described as follows:

- Well OB-30 was sampled and analyzed for TCL volatile organic compounds. This sample was collected to provide an indication for a possible source of TCE and other volatile organic compounds upgradient of well OB-1, where TCE and 1,1-dichloroethene were detected in greatest concentration.

- Both wells OB-8 and OB-21 were sampled to confirm the results of the tris analysis performed on samples collected in April 1988.

- A soil sample, collected approximately 15 feet west of well OB-21 was analyzed for tris to address the possibility of a surface spill in this part of the study area.

Table 4-11
Grain Size Distribution of Sediment Samples
New Castle Spill Site

Sample Location	Percent Retained				Percent Passing Through Sieve # 200
	Sieve # 4	Sieve # 10	Sieve # 40	Sieve # 200	
GS - 1	0	0	5	38	57
GS - 2	0	0	17	30	53
GS - 3	0	0	4	12	84

The analytical results of the additional samples collected on 22 June 1988 are presented in Table 4-12. The TCL volatile analysis performed on well OB-30 indicates the absence of TCE or any other volatile organic compound. This result indicates that the source of volatile organic compounds detected in well OB-1 is not coming from upgradient (i.e., south) of well OB-30. Therefore, a source for the compounds detected in well OB-1 probably exists between wells OB-1 and OB-30, or to the east of well OB-1.

Tris analysis conducted on samples from wells OB-8 and OB-30 yield concentrations of 3,100 and 110,000 ug/l,respectively. These results confirm the tris distribution observed in these wells during the previous sampling in April 1988. The tris analysis conducted on the soil sample collected west of well OB-21 yields a trace concentration of 11 ug/kg. This result suggests that the elevated tris levels detected in well OB-21 are unlikely the result of past tris spills in the area.

4.4.5 Phase II Sampling

Following review of the Draft Remedial Investigation Report for the New Castle Spill Site, additional sampling and investigation of the surrounding wetland areas were requested by the DNREC. The sampling activities involved recollecting surface water and sediment samples from the six sampling stations established during Phase I (Figure 4-12). A description of the Phase II wetland sampling activities and analyses were as follows:

- Surface water and sediment samples were analyzed for tris and trichloroethene (TCE)

Table 4 - 12
Analytical Results of Additional Samples Collected on 22 June, 1988
New Castle Spill Site

ERM T.R. # / Sample Location	Media	Analysis	Compound / Concentration
9704 / OB - 30	Ground Water	TCL Volatiles	None Detected (ug/l)
9705 / OB - 8	GroundWater	Tris (2-chloropropyl) phosphate	Tris / 3,100 (ug/l)
9706 / OB - 21	Ground Water	Tris (2-chloropropyl) phosphate	Tris / 110,000 (ug/l)
9707 / OB - 21	Soil*	Tris (2-chloropropyl) phosphate	Tris / 11 B (ug/kg)

Qualifiers:
"B"- This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
* - The soil sample value is not dry weight corrected.

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- Surface water analysis also included total (unfiltered) and dissolved (filtered) fractions for iron and manganese.

- Sediment analysis included grain size, percent moisture, and total organic carbon (TOC).

Salinity, pH, and conductivity were field measured and all sample collection followed protocols presented in Section 4 of the QAPP associated with the approved RI/FS Work Plan. Salinity measurements were made using an YSI Model 33 S-C-T meter. Results from these sampling activities are discussed below. Results of the wetland investigation which included wetland delineation/habitat assessment and a macroinvertebrate survey are discussed in section 4.6.

Sampling station WS-1 is located closest to the New Castle Spill Site and the sampling station numbers increase moving further downstream of the site. Station WS-5 is located upstream of the discharge coming from the New Castle Spill Site and is considered representative of background conditions. TCE was not detected in any of the six surface water samples submitted for analysis (Table 4-13). Tris was detected in samples WS-1 through WS-4 at concentrations ranging from 1.2 to 5.4 ug/l. The highest concentration was detected in sample WS-2. Overall, the tris concentrations detected in the Phase II surface water samples were an order of magnitude lower than the levels detected in the initial sampling effort. None detectable levels of tris were observed in samples WS-5 (background) and WS-6 (furthest downstream) during both the initial and Phase II sampling events. In sediment samples, an estimated TCE value of 3 ug/kg was reported at sampling station SD-1; all other sample locations were characterized by none detectable TCE levels. Estimated tris levels of 402 and 300 ug/kg were reported for stations SD-3

Table 4-13
Analytical Results For Phase II Surface Water and Sediment Samples
New Castle Spill Site

ERM T. R. No. / Sample Location / Sample Date / Units	13510 WS-1 11/15/88 ug/L	13511 WS-2 11/15/88 ug/L	13512 WS-3 11/15/88 ug/L	13513 WS-4 11/15/88 ug/L	13514 WS-5 11/15/88 ug/L	13515 WS-6 11/15/88 ug/L
trichloroethene						
Tris(2-chloropropyl)phosphate	3.09 J	5.37	4.37 J	1.15 J		
Total Metals						
Iron	494 J	6090 J	2070 J	1690 J	2140 J	1520 J
Manganese	90 J	2290 J	1480 J	705 J	391 J	402 J
ERM T. R. No.	**13621**	**13620**	**13619**	**13618**	**13617**	**13616**
Sample Date	**11/16/88**	**11/16/88**	**11/16/88**	**11/16/88**	**11/16/88**	**11/16/88**
Dissolved Metals						
Iron	338	51	37	45	45	22
Manganese	174	1980	206	163	71	47

Qualifier Codes:
J: This result should be considered a quantitative estimate.
Note: No concentration is entered for compounds which were not detected.

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Table 4-13 (cont.)
Analytical Results For Phase II Surface Water and Sediment Samples
New Castle Spill Site
(all soil results are dry weight corrected)

ERM T. R. No.	13516	13517	13518	13519	13520	13521
Sample Location	SD-1	SD-2	SD-3	SD-4	SD-5	SD-6
Sample Date	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88
Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Percent Moisture for Organics	19%	54%	70%	66%	45%	40%
Percent Moisture for TOC	38%	51%	75%	64%	51%	49%
trichloroethene	3 J					
Tris(2-chloropropyl)phosphate			402 J	300 J		
TOC (ug/g)	13000	40000	82000	58000	54000	25000

Qualifier Codes:
J: This result should be considered a quantitative estimate.
Note: No concentration is entered for compounds which were not detected.

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and SD-4, respectively. Tris levels at the four remaining sample stations were none detectable.

Results of iron and manganese analyses are also presented in Table 4-13. Combined concentrations of total iron and manganese in surface water ranged from a high of 8.4 mg/l in sample WS-2 to a low of .58 mg/l in sample WS-1. Combined concentrations of dissolved iron and manganese ranged from 2.0 to 0.07 mg/l. Sundstrom et al., (1975) reported that combined iron and manganese levels for water from the Columbia aquifer ranged from 21.0 to 0.02 mg/l. Generally, dissolved manganese levels were within an order of magnitude of the total manganese levels and dissolved iron levels were two orders of magnitude smaller than total iron levels.

Surface water pH values ranged from 6.6 to 7.1 and temperature values ranged from 11°C to 13.5°C (Table 4-14). Specific conductance and salinity levels were highest at the sampling stations furthest downstream of the New Castle Spill Site and correspondingly closest to the sluice gate and the Delaware River. Specific conductance ranged from a low of 81 umhos/cm at station WS-1 to highs of 2,150 umhos/cm and 2,100 umhos/cm at stations WS-5 and WS-6, respectively. Salinity levels ranged from 0 parts per thousand (ppt) at station WS-1 to a high of 1.8 ppt at both stations WS-5 and WS-6.

Sediment pH values measured in the field ranged from 6.9 to 7.6 (i.e., neutral to mildly alkaline). Grain size analyses for sediment samples from each of six sampling stations were tested in accordance with ASTM Method D422. Table 4-15 gives the grain size distribution for the six samples. TOC values were lowest at station SD-1 (13,000 ug/L) located closest to the site (Table 4-13). The highest TOC and percent moisture levels were observed in samples collected at stations SD-3 and SD-4. As mentioned previously, tris was also detected at these two sampling stations. The elevated TOC levels in samples SD-3 and SD-4 correlate with the presence of tris, but may also be related to the higher percentage of moisture collected with each respective sample. Leaching of organic acids from naturally occurring marsh deposits may act as a source of TOC for the local surface waters. Grain size distribution does not correlate with elevated levels of TOC. This is reasonable considering that the sediment samples were collected in a marsh with abundant naturally occurring sources of organic carbon.

4.5 Aquifer Testing

As stated previously, the 24-hour pump test conducted by ERM in newly installed well PW-1 was initiated on 12 May 1988 at an average pumping rate of 36 gpm. The actual pumping rate fluctuated between 38 and 34 gpm over the course of the test. Static ground water elevations, end of test ground water elevations, and total drawdown for all of the wells in the monitoring network are listed in Table 4-16. The total drawdown in the pumping well was approximately 3.8 feet over the duration of the 24-hour test. Analytical results from the two water samples collected during the test are given in Table 4-17.

Water levels in five wells monitored during the test were not affected by the pumping of well PW-1. Three of the wells, OB-28, OB-29, and OB-30, are located approximately 600 feet upgradient of the pumping well. Wells OB-12 and OB-16 were also located outside the radius of influence. Well OB-16 is located approximately 325 feet downgradient of well PW-1 and well OB-12 is located approximately 300 feet east of well PW-1 along the same equipotential line. The cone of depression resulting from the 24-hour pump test extended approximately 50 feet upgradient

TABLE 4-14

FIELD MEASUREMENTS FOR PHASE II
SURFACE WATER AND SEDIMENT SAMPLES

NEW CASTLE SPILL SITE

Sample Station	pH	Specific Conductance (umhos)	Temperature (°C)	Salinity (ppt)
WS-1	7.1	81	12	0.0
SD-1	7.2	--	--	--
WS-2	6.7	308	13	0.1
SD-2	7.1	--	--	--
WS-3	6.6	1,280	13.5	1.0
SD-3	6.9	--	--	--
WS-4	6.6	1,950	13	1.7
SD-4	7.1	--	--	--
WS-5	6.7	2,150	11.5	1.8
SD-5	7.6	--	--	--
WS-6	6.6	2,100	11	1.8
SD-6	7.0	--	--	--

WS = Designates surface water sample
SD = Designates stream sediment sample
ppt = Parts per thousand
-- = Indicates not applicable

TABLE 4-15

GRAIN SIZE DISTRIBUTION FOR
PHASE II SEDIMENT SAMPLES

NEW CASTLE SPILL SITE

Sample Location	Percent Retained Sieve # 4	Sieve # 10	Sieve # 40	Sieve # 200	Percent Passing Through 200	Unified Soil Classification
GS-1	6.4	3.4	23.3	16.1	50.8	Silty sand trace clay and gravel with organic matter
GS-2	0.0	0.0	2.2	8.4	89.4	Clayey silt trace fine sand, very organic
GS-3	0.0	0.0	2.2	5.8	92.0	Clayey silt trace fine to medium sand, very organic
GS-4	0.0	0.0	6.4	11.6	82.0	Sandy silt little clay, very organic
GS-5	0.0	0.0	0.8	2.8	96.4	Clayey silt trace fine sand, slightly organic
GS-6	0.0	0.0	0.6	1.2	98.2	Clayey silt trace fine sand, organic

Table 4-16
Water Table Elevations Before and After the Pump Test
New Castle Spill Site

Well	Top of Casing Elevation	Depth to Water		Water Table Elevation		Total Drawdown	Well Depth *
		Static	End of Test	Static	End of Test		
OB-1	9.8	8.54	8.59	1.26	1.21	0.05	24.59
OB-2	6.22	5.05	5.31	1.17	0.91	0.26	12.3
OB-3	6.99	5.9	6.12	1.09	0.87	0.22	12.01
OB-4	7.56	6.42	6.62	1.14	0.94	0.2	12.19
OB-5	8.39	7.27	7.59	1.12	0.8	0.32	12.07
OB-6	7.77	6.67	7.23	1.1	0.54	0.56	12.03
OB-7	6.74	5.58	6.2	1.16	0.54	0.62	11.24
OB-8	5.58	4.52	5.34	1.06	0.24	0.82	11.45
OB-9	7	5.9	6.5	1.1	0.5	0.6	12.97
OB-10	7.44	6.34	6.6	1.1	0.84	0.26	12.21
OB-11	9.3	8.13	8.21	1.17	1.09	0.08	12.7
OB-12	9.9	8.76	8.78	1.14	1.12	0.02	13
OB-16	9.26	8.48	8.5	0.78	0.76	0.02	12.3
OB-21	8.28	7.39	7.48	0.89	0.8	0.09	14.76
OB-24	5.54	4.46	4.79	1.08	0.75	0.33	14.65
OB-25	5.16	3.94	4.1	1.22	1.06	0.16	13.12
OB-27	8	6.81	6.89	1.19	1.11	0.07	18.45
OB-28	8.28	7.07	7.07	1.21	1.21	0	16.2
OB-29	11.13	9.89	9.89	1.24	1.24	0	17.57
OB-30	14.33	13.05	13.07	1.28	1.26	0.02	21.14
MW-1	10.57	9.46	9.68	1.11	0.89	0.22	31
MW-2	7.89	6.83	7.22	1.06	0.67	0.39	28
MW-3	9.09	7.93	8.19	1.16	0.9	0.26	28
MW-4	10.51	9.03	9.11	1.48	1.4	0.08	34
MW-5	11.19	10.15	10.57	1.04	0.62	0.42	32.5

* from ground surface
\- all values given in feet

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Table 4-17
Analytical Results of Ground Water Samples
Collected During Pump Test
New Castle Spill Site

ERM T. R. No. Sample Location Sample Date Units	8337 PW-1 60 min 5/12/88 ug/l	8338 PW-1 23 hrs 5/13/88 ug/l
Volatile Organics		
1,2-Dichloroethene	3 J	
Trichloroethene	41	31
Tentatively Indentified		
(Volatiles)		
Unkown	4 J	5 J
Semi Volatiles		
Bis(2-Ethylhexyl)Phthalate	4 B*	9 B*
Tentatively Indentified		
(Semi Volatiles)		
Unknown	14 J	16 J
Additional Semi Volatiles		
Tris(2-chloropropyl) Phosphate	520	420
Inorganics		
Iron	268	345
Manganese	3230	2960
COD mg/l	9.4 B	5.6 B
TOC mg/l	5.6	8.6
phenols mg/l		
cyanide mg/l		

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"*" - This result is from a reextraction analysis.

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(i.e., south) and 140 feet downgradient (i.e., north) of pumping well PW-1.

Static and end of test ground water configuration maps were generated and are included as Figures 4-13 and 4-14, respectively. The static ground water configuration indicates a ground water flow direction across the NCBW&L front lawn area and the New Castle Spill Site generally to the north-northwest. The end of test ground water configuration indicates a northwesterly trending cone of depression as a result of ground water pumping. The data collected from the observation wells were evaluated by the Jacob Straight Line Method of pump test data analysis to obtain transmissivity, storativity and hydraulic conductivity values. A justification for the use of this method is included in Appendix E.

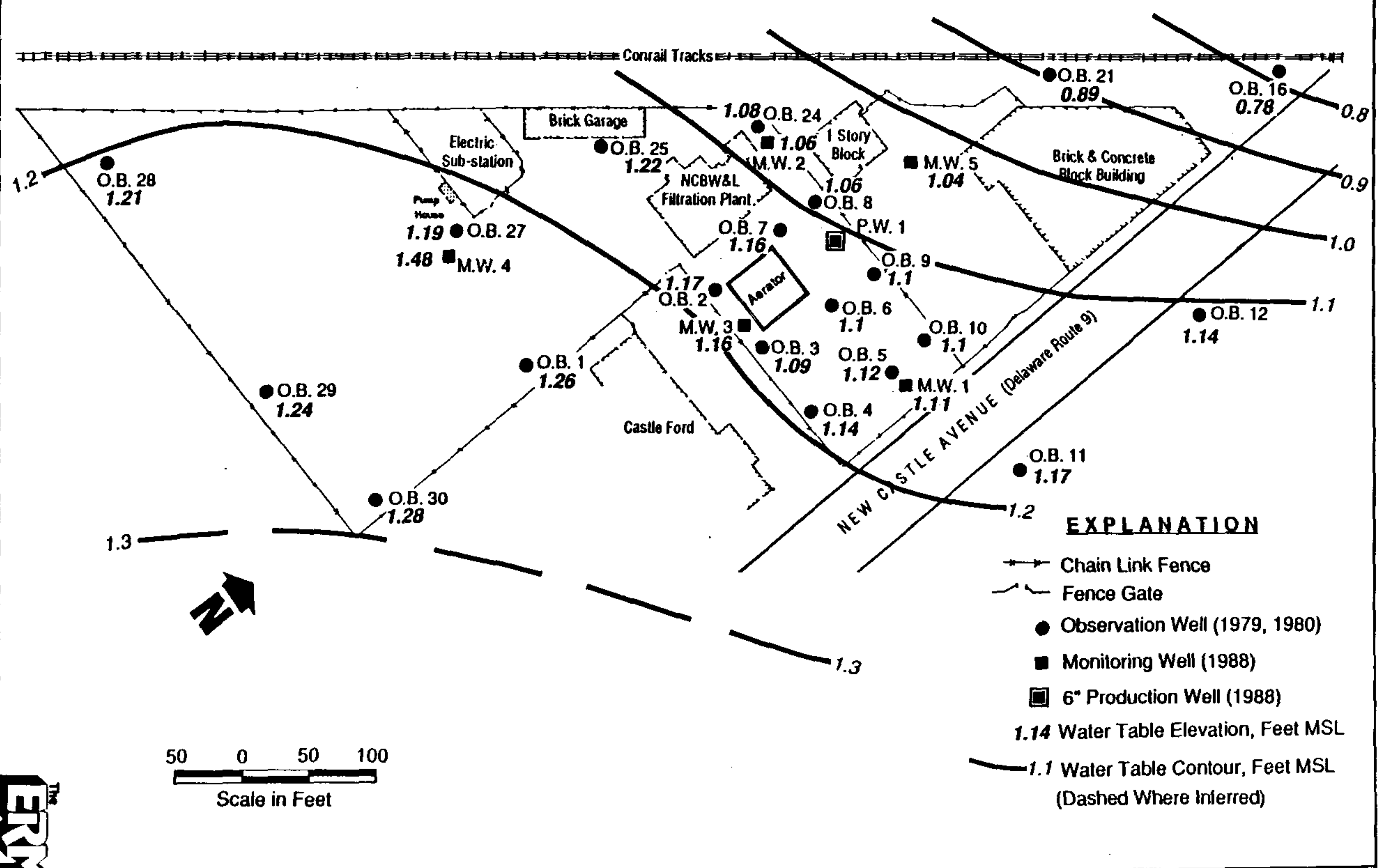
In the Jacob Straight Line Method, time-drawdown data are plotted as a semilog graph. A best fit straight line is drawn through the points to intercept the zero drawdown axis. From the graph, both the drawdown for one log cycle of time (h_0-h) and the time at which the straight line intercepts the zero drawdown axis (T_0) are determined. With these values, the transmissivity (T) and storativity (S) for the aquifer can be calculated using the following equations:

$$T = \; = \frac{264Q}{(h_0 - h)}$$

$$S = \; = \frac{TT_0}{4,790(r^2)}$$

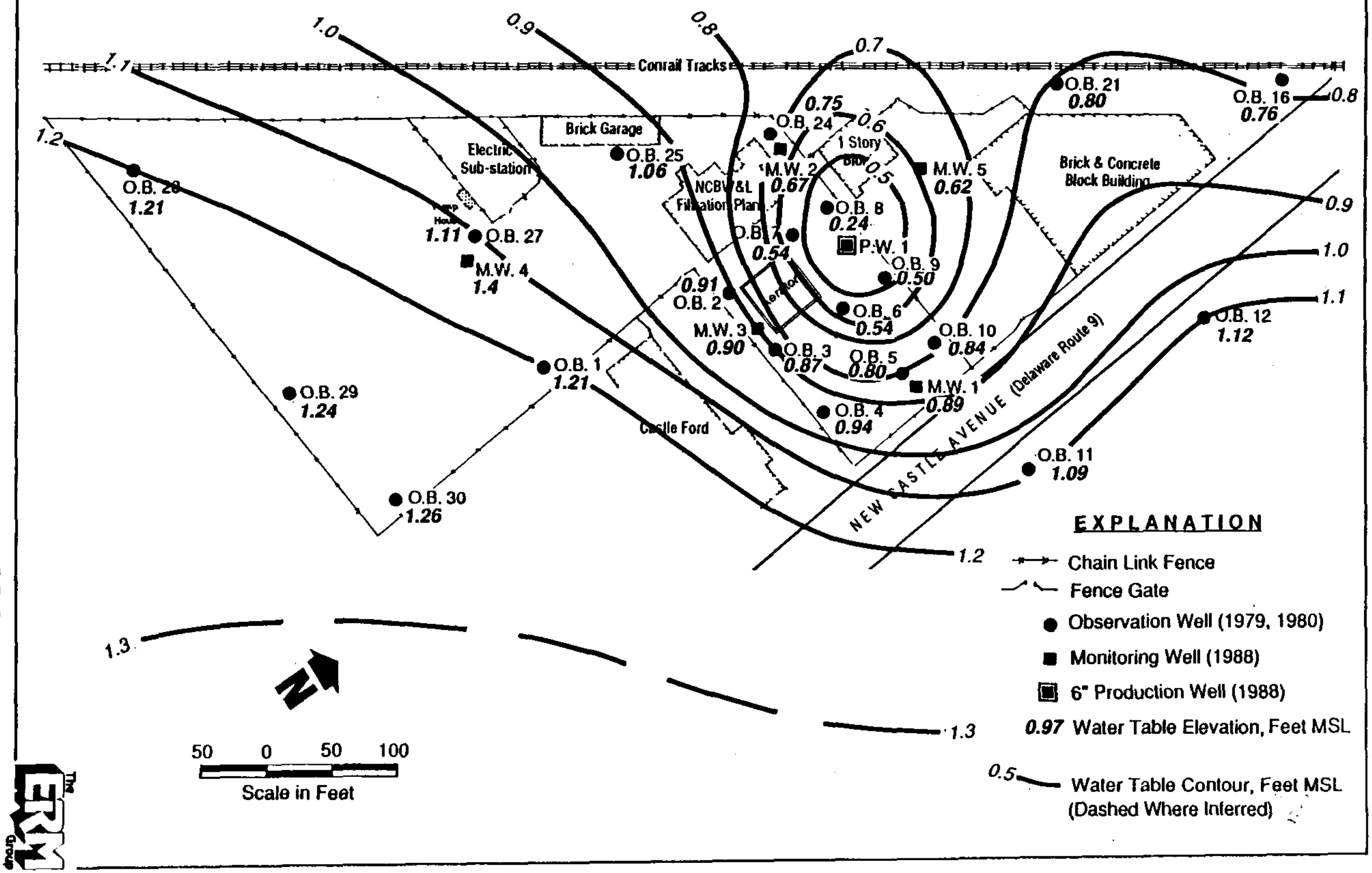
31006 01 06

Figure 4-13
Water Table Contour Map, Columbia Aquifer Prior to Pump Test - 12 May 1988
New Castle Spill Site



31006 01 06

Figure 4-14
Water Table Contour Map, Columbia Aquifer
End of Pump Test - 13 May 1988
New Castle Spill Site



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4.6 Phase II Environmental Assessment

4.6.1 Wetland Delineation/Habitat Assessment

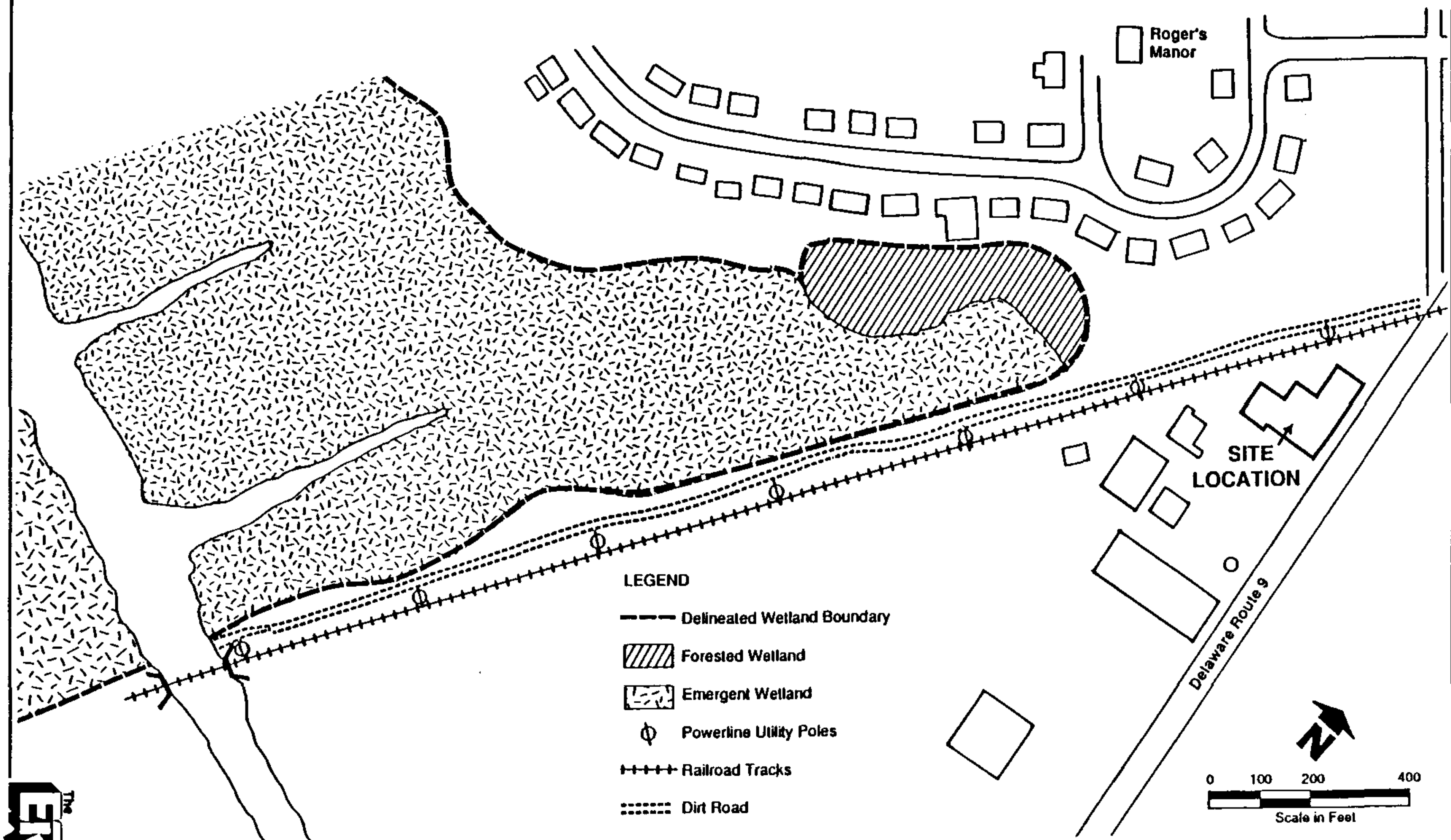
Wetlands located southwest of the New Castle Spill Site were delineated in the field on 16 November 1988 using the Delaware State Wetland Map for New Castle County (Photograph No. 35-8) and the procedures outlined by the United States Corps of Engineers (USCOE). Because of the vast extent of the wetlands, only the areas in the vicinity of the surface water and sediment sampling stations and the New Castle Spill Site were delineated and observed. Emergent and forested wetlands were the two major types of wetland habitats found within the study area. The approximate boundaries of these wetland areas, as delineated by ERM, are shown in Figure 4-16. The United States Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) map (Wilmington south, Del-NJ quad) presents similar wetland boundaries as shown in Figure 4-17.

Vegetation

A list of plant species observed during the field survey within and adjacent to the wetlands is presented along with their USCOE indicator status in Table 4-19. Because the delineation was performed in late fall, identification of the vegetation was limited to bare trees and shrubs, partially decomposed remains of herbaceous vegetation and leaf litter. Although the table presented is not a complete list of all the vegetation present, the listed plant species were observed in the field, and are representative of the wetland's vegetation. No additional plant inventories were utilized to compile this plant list.

31006-04

Figure 4-16
Wetland Boundary Map
New Castle Spill Site



Source: Modification of the State of Delaware Wetland Map (Photo No. 35-8)

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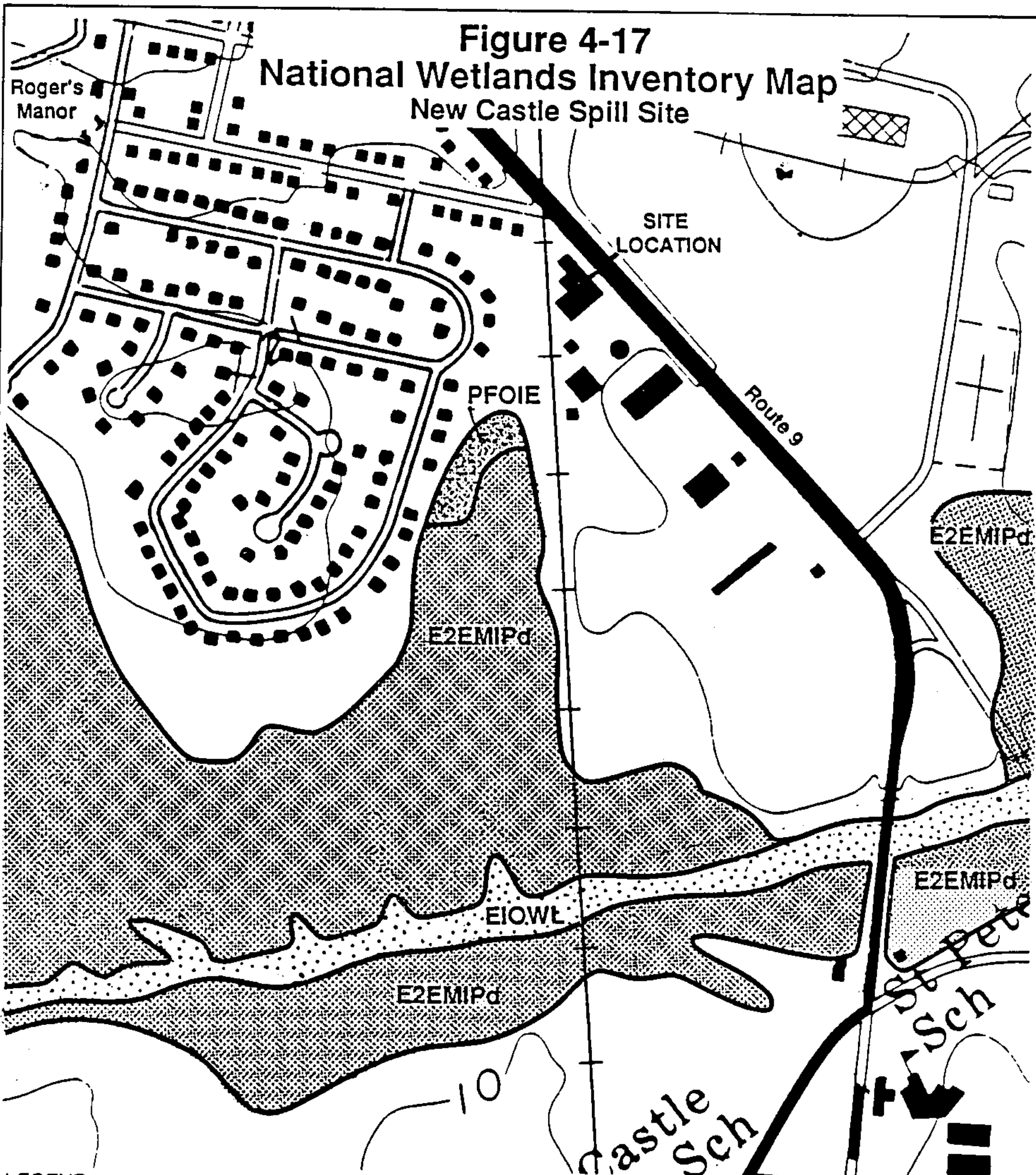
Figure 4-17
National Wetlands Inventory Map
New Castle Spill Site



LEGEND

PFOIE	Palustrine forested, broad-leaved deciduous, seasonal saturated
E2EMIPd	Estuarine, intertidal emergent, persistent, irregular, partially ditched
EIOWL	Estuarine, subtidal open water

Source: National Wetland Inventory, U.S. Department of the Interior, Fish and Wildlife Service
Topographic Quadrangle, Wilmington South, Del-NJ

31006-04

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Table 4-18
Aquifer Characteristics Determined by the Jacob Straight Line Method
of Pump Test Analysis
New Castle Spill Site

Well #	Top of Casing Elevation	Elevation of Screened Interval	T (gal/day/ft)	S (dimensionless)	K (gal/day/ft2)
OB-1	9.8	? to -15.9	-	-	-
OB-2	6.22	-0.9 to -5.9	67000	0.015	3040
OB-3	6.99	0.2 to -4.8	59000	0.022	2700
OB-4	7.56	0.6 to -4.4	42000	0.046	1820
OB-5	8.39	1.5 to -3.5	69000	0.023	2930
OB-6	7.77	1.0 to -4.0	48000	0.007	2070
OB-7	6.74	0.8 to -4.2	50000	0.002	2070
OB-8	5.58	-0.6 to -5.6	48000	0.0002	2160
OB-9	7	-0.9 to -5.9	48000	0.005	2070
OB-10	7.44	0.5 to -4.5	59000	0.026	2580
OB-11	9.3	1.8 to -3.2	68000	0.044	2970
OB-12	9.9	1.9 to -3.1	-	-	-
OB-16	9.26	2.1 to -2.9	-	-	-
OB-21	8.28	-1.3 to -6.3	-	-	-
OB-24	5.54	-4.0 to -9.0	56000	0.002	2450
OB-25	5.16	-2.9 to -7.9	-	-	-
OB-27	8	-5.3 to -10.3	-	-	-
OB-28	8.28	-2.7 to -7.7	-	-	-
OB-29	11.13	-1.4 to -6.4	-	-	-
OB-30	14.33	-1.6 to -6.6	-	-	-
MW-1	10.57	-17.4 to -22.4	-	-	-
MW-2	7.89	-17.2 to -22.2	65000	0.002	2830
MW-3	9.09	-15.9 to -20.9	98000	0.0002	4450
MW-4	10.51	-20.6 to -25.6	-	-	-
MW-5	11.19	-17.9 to -22.9	49000	0.008	2030

- indicates insufficient drawdown for the determination of aquifer characteristics

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TABLE 4-19
Species of Vegetation Observed
During the Wetland Delineation
New Castle Spill Site

Emergent Wetland : E2EM1Pd

Scientific Name	Common Name	Indicator [1] Status
Phragmites communis *	Giant reed	FACW
Typha angustifolia *	Narrow-leaved cattail	OBL
Hibiscus palustris	Crimson-eyed rose mallow	OBL
Scirpus sp.	Bulrush	OBL-FACW
Juncus effusus	Soft rush	FACW+
Sagittaria sp.	Arrowhead	OBL
Polygonum persicaria	Ladysthumb smartweed	FACW
Lythrum salicaria	Purple loosestrife	FACW+
Lemna sp.	Duckweed	OBL

Forested Wetland : PFO1E

Scientific Name	Common Name	Indicator [1] Status
Liquidamber styraciflua *	Sweet gum	FAC
Acer saccharum *	Silver maple	FACW
Viburnum recognitum *	Northern arrowwood	FACW-
Cornus amomum *	Silky dogwood	FACW
Impatiens capensis	Spotted jewelweed	FACW
Salix nigra	Black willow	FACW+
Onoclea sensibilis	Sensitive fern	FACW
Sambucus canadensis	Elderberry	FACW
Acer rubrum	Red maple	FAC
Lonicera japonica	Japenese honeysuckle	-
Rubus allegheniensis	Blackberry	-
Rosa multiflora	Multiflora rose	-

Area in the vicinity of the Railroad

Scientific Name	Common Name	Indicator [1] Status
Phragmites communis *	Giant reed	FACW
Acer saccharum	Silver maple	-
Apocynum androsaemifolium	Spreading dogbane	-
Rosa multiflora	Multiflora rose	-
Lonicera japonica	Japenese honeysuckle	-
Juncus effusus	Soft rush	FACW

[1] Indicator statuses from Corps of Engineers Wetlands Delineation Manual-Appendix C , Section 1
* Dominant species

Key to indicator statuses:

OBL - Obligate Wetland Plants	>99% of the time found in wetlands
FACW - Faculative-Wet Wetland Plants	67% to 99% of the time found in wetlands
FAC - Faculative Wetland Plants	33% to 67% of the time found in wetlands
-	Upland Species

"+" and "-" : Modifiers used to indicate that a plant species has a greater or lesser probability of occurring in a wetland than a plant species that has the general indicator status.

The ERM Group

AR300744

The emergent wetland, comprising much of the total wetland area, is dominated by wetland hydrophytes such as giant reed and cattails. Other less dominating wetland vegetation includes crimson-eyed rose-mallow, softrush, arrowhead, bulrush, ladysthumb smartweed, purple loosestrife and duckweed. The USFWS-NWI map classifies the emergent wetland as an estuarine, intertidal-persistent emergent wetland (E2EM1Pd). The State of Delaware wetland map shows the emergent wetland as being dominated by giant reed and cattails. This wetland area is bounded to the east by a dirt road and railroad tracks and to the north by the smaller forested wetland and a residential development. The wetland extends to the south and west beyond the field sampling/study area as shown in Figure 4-17.

The forested wetland is dominated by wetland trees and shrubs such as sweet gum, silver maple, northern arrowwood, and silky dogwood. Other less abundant wetland and upland vegetation observed includes: jewelweed, black willow, sensitive fern, elderberry, red maple, honeysuckle, blackberry, and multiflora rose. The USFWS-NWI map classifies the forested wetland as a palustrine forested, broad-leaved deciduous, seasonal saturated wetland (PF01E). The western portion of the forested wetland adjoins properties within the residential development.

Vegetation within two shallow ditches on both sides of the railroad tracks is dominated by giant reed. Other vegetation present includes silver maple saplings, spreading dogbane, multiflora rose, and honeysuckle. Soils adjacent to the railroad tracks consist of fill material; however, since hydrophytic vegetation and wetland hydrology exists, this area is also classified as a wetland. No areas of stressed vegetation were observed within the wetland areas or within the vicinity of the railroad tracks.

There are four plant species historically known to occur within the New Castle area that are listed by the DNREC Natural Heritage Program as being species of special concern. These plant species and their state rank are as follows: dogbane (Apocynum cannabinum) - SH, American frog's-bit (Limnobium spongia) - S1, bristly crowfoot (Ranunculus pensylvanicus) - S1, hooded skullcap (Scutelaria galericulata) - SH. The S1 denotes that there are 5 or fewer occurrences and the SH means that the species has not been seen in the past 15 years. None of these species was observed during the field reconnaissance. Letters requesting this information and the DNREC's reply are presented in Appendix I.

Soils

Based on the New Castle County Soil Survey, two hydric soil associations occur in the wetland areas: Tidal Marsh and Othello Silt Loam. The Tidal Marsh association occurs within the emergent wetland while the forested wetland is composed of the Othello Silt Loam association. Dark black saturated soils were observed at all sampling stations in the emergent wetland, indicating hydric soils.

The soils in the vicinity of the site and along the railroad and transmission line right-of-way are classified by the soil survey as Aldino-Keyport-Mattapex Urban Land Complex. This mapping unit consists of Aldino, Keyport and Mattapex soils, but have been disturbed for residential and industrial development.

Wildlife

The birds, mammals and amphibians observed in the wetland areas during the initial RI investigation and Phase II sampling activities are presented in Table 4-20. A total of 16 species of birds were observed during the field activities. Wood ducks, mallards, and a great blue heron were observed in the emergent wetland, while the other birds were located in the forested wetland. Approximately six muskrat dens and several frogs were observed within the emergent wetland. According to the DNREC Division of Fish and Wildlife, there are no rare, threatened, or endangered species of animals present on or in the vicinity of the New Castle Spill Site. Letters requesting this information and the DNREC's reply are presented in Appendix I.

Wetland Community and Target Populations

An emergent wetland dominated mostly by giant reed generally has little food value to waterfowl or to a detritus based food chain. However, giant reed does serve as food for muskrats and supports insects which serve as food for many fish and birds. The extensive stands of giant reed do provide cover and nesting sites for waterfowl, wading birds, mammals and fish. The open water within the emergent wetland supports a diverse population of fish such as brown bullhead, carp, golden shiner, pumpkinseed sunfish, bluegill, mummichog, mud minnow and mosquitofish (Dave Carter, 1989). From the data gathered, the potential receptors or target populations for the wetlands adjacent to the New Castle Spill Site include macroinvertebrates, fish, birds, and mammals. The results of the surface water analyses performed during the initial RI and the Phase II sampling show low levels of tris and questionable levels of TCE, all of which are well below the Ambient Water Quality Criteria (U.S. EPA, 1986) as presented in Table 4-21. In summary, the results of the habitat assessment

TABLE 4-20
Species of Wildlife Observed
During the Wetland Delineation
New Castle Spill Site

Birds

Scientific Name	Common Name
Cardinalis cardinalis	Northern cardinal
Sturnus vulgaris	European starling
Ardea herodias	Great blue heron
Melospiza melodia	Song sparrow
Corvus brachyrhynchos	American crow
Anas platyrhynchos	Mallard duck
Aix sponsa	Wood duck
Zonotrichia albicollis	White-throated sparrow
Melanerpes caralinus	Red-bellied woodpecker
Junco hyemalis	Slate-colored junco
Cyanocitta cristata	Bluejay
Zenaida macroura	Mourning dove
Mimus polyglottos	Mockingbird
Parus atricapillus	Black-capped chickadee
Buteo jamaicensis	Red-tailed hawk
Carduelis tristis	American goldfinch

Mammals

Sciurus carolinensis	Gray squirrel
Ondatra zibethicus	Muskrat

Amphibians

Rana sp.	Frog

TABLE 4-21

Comparison of Surface Water Concentrations To AWQC And Toxicity Values

Compound	Maximum Surface Water Concentration (mg/L)	AWQC (mg/L) Acute	AWQC (mg/L) Chronic	Toxicity Value * (mg/L)
trans-1,2-Dichloroethene	Not Analyzed	11.6	-	None Listed
Trichloroethene	Not Detected	45	21.9	40.7 **
tris(2-Chloropropyl)phosphate	0.042	None Established		0.240 ***

AWQC = Ambient Water Quality Criteria (US EPA, 1986)

*Most sensitive aquatic species listed in Verschueren, 1983
**96 hour LC50 (flow-through test) - Pimephales promelas Rafinesque (fathead minnow)
***No toxicity values or AWQC for tris(2-chloropropyl)phosphate
Based on more toxic compound - tris(2,3-dibromopropyl)phosphate
96 hour LC50 (static test) - rainbow trout sac fry
- fingerling (1.45 ppm)

indicate that the wetland habitats support a diverse flora and fauna unaffected by the New Castle Spill Site.

4.6.2 Macroinvertebrate Survey

Table 4-22 presents the results of the qualitative macroinvertebrate survey conducted at each station location. A combined total of 5 different species totaling 179 specimens were collected from the 6 stations. The largest numbers of total organisms and taxa were collected at stations 1, 2, and 3 located closest to the site. Small Oligochaeta worms (10 to 25 mm in length) dominated the samples and comprised 88 percent of the total number of specimens collected. Other species collected included leeches, two types of snails and a small clam.

The depth of the water at sampling stations 1, 2, 3, and 4, where the benthic organisms were collected was approximately 4 to 6 inches. No flow was detected at any of these sampling locations. At sampling stations 5 and 6 the flow was minimal and the water depth was approximately 6 to 12 inches. The water level within the emergent wetland is controlled by DNREC Division of Mosquito Control by operating the sluice gate. The sluice gate is located south of the New Castle Spill Site (see Figure 4-12) at the confluence of the major drainage ditch and the Delaware River.

The grain size analyses presented in Section 4.4.5 shows that soils at sampling stations 2, 3, 5, and 6 were clayey silt, while station 1 soils were composed of silty sand and station 4 soils were sandy silt. Stations 2 and 3 contain more organic matter than the other stations, which may be the reason for the greater number of organisms and the larger number of taxa present.

TABLE 4-22

Results of the Macroinvertebrate Survey
Conducted on 16 November 1988
New Castle Spill Site

	Sampling Stations						
Organism	B-1	B-2	B-3	B-4	B-5	B-6	Total
Annelida							
Oligochaeta	41	42	57	7		11	158
Hirudinea		1	1				2
Gastropoda							
Physidae							
Physa	1	14	1	1			17
Planorbidae							
Gyraulus		1					1
Pelecypoda							
Sphaeriidae			1				1
Total Organisms	42	58	60	8	0	11	179
Number of Taxa	2	4	4	2	0	1	5

As part of a wetland restoration program, the DNREC Division of Fish and Wildlife collected macroinvertebrates from various locations throughout the emergent wetland adjacent to the New Castle Spill Site. The results of the survey are presented below according to relative abundance (Dave Carter, 1989).

Species	Abundance
Springtails	30%
Mosquito larvae	28%
Oligochaete worms	14%
Amphipods	7%
Physidae snails	5%
Planorbidae snails	5%
Sphaeriidae (fingernail clam)	5%
Cranefly larvae	2%
Diptera fly larvae	2%
Predaceous water beetle	2%

The data presented above shows that more species were collected as compared to ERMs survey. Reasons for the difference can be attributed to different sampling methods, sampling in more varied habitats, greater sampling effort and seasonal variations.

The organisms listed above are typical of a wetland community because they can tolerate the harsh physical conditions of the wetland environment. These conditions include periodic drying, seasonal water level fluctuations, stagnate water and anaerobic sediments. If chemicals were present in the water and sediment at toxic levels, then very few to no macroinvertebrate species would be present within the marsh community. However, the macroinvertebrate and chemical data collected by ERM and macroinvertebrate data from DNREC, do not indicate that potential receptors of the spill were adversely affected.

The emergent wetland is not a natural intertidal marsh community because the sluice gate controls the flow into the wetland; therefore, tidal and salinity fluctuations are not experienced and no comparisons can be made to healthy intertidal marsh communities. Also, at this time, DNREC does not have available macroinvertebrate data from a similar emergent wetland community, so no direct comparisons were made.

SECTION 5

CONCLUSIONS

5.1 Columbia Aquifer

The unconfined Columbia aquifer which underlies the New Castle Spill Site is composed primarily of a medium grained sand with an average transmissivity of 60,000 gal/day/ft and approximate saturated thickness of 23.5 feet. In the northern part of the study area, ground water flows in a northerly direction at a rate of 1.0 ft/day, while in the southern part of the study area, ground water flows in a westerly direction toward the marsh at a rate of 0.5 ft/day. Ground water within the study area is not tidally influenced.

The drilling program defined three distinct stratigraphic units across the study area: a surficial layer consisting of a variable sequence of clay, silty clay and silty sand; an intermediate layer (i.e., Columbia aquifer) consisting of medium grained sand; and a very dense, stiff clay layer at an average depth of 30 feet which designates the top of the underlying Potomac Formation. Vertical permeability test results ranged from 1.48×10^{-8} to 4.83×10^{-8} cm/sec. A minimum of 5-feet of this material was encountered in each of the newly installed wells and is considered to be continuous across the study area. Information gathered from other wells within the study area define this clay as the top of an 85-foot-thick sequence of clay, silty clay, silts and sands which serve to isolate the Columbia aquifer from the underlying Upper Potomac aquifer.

5.2 Aquifer Interconnection

Both the Columbia and Upper Potomac aquifers are isolated by a sequence of clay, silty clay, silt and sand that are continuous throughout the study area. The impermeable nature of this confining clay sequence is reflected in the five Shelby tube samples of this material which yield an average vertical permeability of 2.87×10^{-8} cm/sec. Under static ground water conditions, 160 years are required for the movement of ground water to a depth of 1-foot into this clay. Likewise, movement of ground water to a depth of 10-feet into the clay would require 1,600 years. Additional information supporting a lack of aquifer interconnection includes; pump test information, and water levels in the Upper Potomac aquifer.

The pump test of the upper Potomac aquifer, conducted in April-May 1986 yields data from well PH that indicates a typical confined response to pumping. Additionally, the storage coefficient calculated for the upper Potomac from this test (0.00011) is indicative of a confined system. A final line of evidence, with respect to the April-May pump test, is the stability of the water levels in the Columbia aquifer during the first 12 hours of the test, and prior to the recharge resulting from the ponding of discharge water on the surface. Stability of the water levels from those wells in close proximity to the pumping well (PW-11) demonstrate a lack of interconnection between the Columbia and Potomac aquifers.

The average depth to the top of the confining clay is approximately 30-feet BLS. As evidenced by depth-to-water measurements obtained from well PH, both recently and in 1986, the potentiometric surface of the upper Potomac aquifer extends approximately 15 feet above its confining layer. These artesian

ORIGINAL (RED)

conditions are supportive of the clays continuity throughout the study area.

5.3 Environmental Sampling

Several different media, including both on-site soils and ground water, in addition to sediments and surface water from the wetlands, were collected and analyzed as part of this remedial investigation. The significance of, and risks associated with the chemical quality of these various media are discussed in detail in Volume II titled "Environmental Assessment".

5.3.1 Soils

The occurrence and distribution of tris, which was detected in 9 of 15 soil samples at concentrations ranging from 54 to 11,740 ug/kg, reflects higher concentrations in those soils of the recognized spill source area. Within the spill source area, tris was detected to a depth of 8 feet. However, the mobility of tris is limited both by its preference to adsorb onto the soil matrix underlying the New Castle Spill Site, and by the fact that the area of highest tris concentration in the soils is presently capped by asphalt and concrete. Therefore, additional leaching of tris into the ground water from a "washing effect" by infiltrating rain water is significantly restricted.

TCE was conspicuously absent from all soil samples submitted for analysis as part of this study. It is therefore concluded that the presence of TCE in ground water originates from an upgradient and off-site source and therefore can not be attributed to past activities at the New Castle Spill Site

The trace and non-quantifiable concentrations of Polynuclear Aromatic Hydrocarbons (PAH's) in soils of the spill source area had a tendency to decrease with depth and are likely derived from asphalt paving.

5.3.2 Ground Water

Detectable and quantifiable concentrations of tris, ranging from 17.1 to 110,000 ug/l, were identified in 7 of 17 wells sampled. The distribution of tris in the Columbia aquifer is consistent with the spill source area, and reflects a reduced mobility by its occurrence primarily in the upper 10-feet of the aquifer. This is evidenced by higher tris concentrations in the "OB" series wells, screened at the top of the Columbia aquifer, in contrast to the "MW" series wells, screened at the base of the same aquifer. In addition to tris, TCE was the other predominant compound identified in the 17 ground water samples collected.

The distribution of TCE, which was detected in 8 of 17 samples, ranged in concentration from 1 to 120 ug/l. As discussed in Section 5.3.1, the absence of this compound in the soil samples submitted for analysis indicate an upgradient and off-site source for TCE. The occurrence and distribution of TCE in the ground water samples suggests that this off-site source may exist either to the south or east of the New Castle Spill Site.

5.3.3 Wetlands

The NCSS is bordered to the west by wetlands that support a diverse flora and associated wildlife community. Samples collected from within the wetlands possessed quantifiable concentrations of tris ranging from none detected to 42 ug/l in surface water while wetlands sediments yielded results of none-detected. Confirmatory sampling conducted in June 1988 yielded order-of-magnitude lower results for surface water, while 2 sediment samples contained quantifiable tris concentrations of 300 and 402 ug/kg. However, based on investigations conducted as part of this study, it is concluded that potential receptors dwelling within the wetland, such as macroinvertebrates, fish, birds and mammals, are not affected by the New Castle Spill Site.

An investigation of DNREC files to identify potential users of groundwater from the Columbia aquifer within a 2-mile radius north of the New Castle Spill Site, and 1-mile south of the New Castle Spill Site indicate that there are no withdrawls of ground water from the Columbia for either domestic or municipal purposes.

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APPENDIX A

LIST OF CHEMICALS POSSIBLY STORED AT THE NEW CASTLE SPILL SITE

ISOCYANATES

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
PAPI, MR, MRS, Isonate 135, 901 Rub. M	Upjohn, Mobay, Rubicon	Crude MDI
IPDI	Scholven	Isophorone diisocyanate
TDI	Du Pont, U.C.C. Rubicon	Toluene diisocyanate
TDR, TRF, TCPA	Du Pont	Crude TDI

FIRE RETARDANTS

3CF	U.C.C.	Tris (Beta-chloroethyl) phosphate
CEF	Stauffer	Tris (Beta-chloroethyl) phosphate
C-22R	Monsanto	Chlorine containing phosphate ester
Fyrol 6	Stauffer	Diethyl N,N-bis (2-hydroxyethyl) aminomethylphosphonate
T-23P	Michigan Chemical	Tris (2,3-dibromopropyl) phosphate
PCF	Stauffer	Tris (Beta-chloropropyl) phosphate
Antiblaze 78	Mobil	Chlorine containing phosphate ester

RIGID POLYOLS

SA-2002	Dow Chemical	Amine Polyol
RN-360	" "	Sucrose Polyol
Clycerine	" "	Glycerine
RF-230	Olin	Dextrose plus trichlorobutylenaoxides

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
70-600	"	Amine Polyol
71-530	"	Sucrose amine polyol
TMP	Celanese	Trimethylol propane
C-150	Jefferson	Diol
G-400	"	Glycerine polyol
R-350X	"	Aromatic amine polyol
R-650X	"	Aromatic amine polyol
R-480	"	Sucrose amine polyol
SF-265	"	Amine polyol
Isonol 100	Upjohn	Propoxylated aniline
50-810	U.C.C.	Ethoxylated aniline based polyol
BDE-361	"	Sucrose based polyol
BDE-400	"	Sucrose amine polyol
BDE-435	"	Sucrose polyol
BE-375	"	Aromatic polyol
BET-530	"	Aromatic polyol
LA-475	"	Amine polyol
LA-700	"	Amine polyol
MT-240	"	Glycerine polyol
LG-650	"	Glycerine polyol
LS-490	"	Sucrose polyol
50-1180	"	Ethoxylated aniline polyol

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
PPG-425	"	400 mol. wt. diol
DPG	"	Dipropylene glycol
DEG	"	Diethylene glycol
T-221	"	Aromatic polyol containing phosphorous
EXP-154	Wyandotte	Pentaerythritol polyol
PL-492	"	Diol
PEP-450	"	Pentaerythritol polyol
PEP-550	"	Pentaerythritol polyol
PEP-650	"	Pentaerythritol polyol
PL-463	"	Aromatic polyol containing phosphorous
P-208	"	Phosphorous polyol
TP-440	"	Trimethylolpropane polyol
PL-639	"	Aromatic polyol
G-2406	Atlas (ICI)	Sorbitol polyol
G-2408	" "	Sorbitol polyol
G-2410	" "	Sorbitol polyol
G-2450	" "	Sorbitol polyol
P-2705	Witco	Phenol formaldehyde polyol
Urol-11	UCT	Mixed diols and triols

FLEXIBLE POLYOLS

CP-4601	Dow Chemical	4000 mol. wt. triol
CP-4701	" "	4500 mol. wt. triol

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
CP-3001	" "	3000 mol. wt. triol
2025	" "	250 mol. wt. triol
E-2000	Jefferson	2000 mol. wt. diol
PPG-2000	"	2000 mol. wt. diol
SF-6500	"	6500 mol. wt. triol
31-28	U.C.C.	5000 mol. wt. polyol + polyacrylonitrile
31-45	"	3000 mol. wt. polyol + polyacrylonitrile
DPG-1025	"	1000 mol. wt. diol
34-45	"	3000 mol. wt. polyol + polyacrylonitile
LHT-42	"	4400 mol. wt. triol
LHT-112	"	1500 mol. wt. triol
34-28	"	5000 mol. wt. polyol + polyacrylonitrile and polystyrene
PPG-2025	"	2000 mol. wt. diol
PPG-1225	"	1200 mol. wt. diol
24-32	"	2800 mol. wt. polyol + polyacrylonitrile
LC-60	"	3000 mol. wt. polyol
A-1228	Witco	6000 mol. wt. triol
K-342	"	3000 mol. wt. triol
K-350	"	3500 mol. wt. triol
KO-621	"	2000 mol. wt. diol

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
P-2010	Wyandotte	2000 mol. wt. diol
P-1010	"	1000 mol. wt. diol
	SURFACTANTS	
L-5420	U.C.C.	Silicone surfactant
L-5340	"	Silicone surfactant
Y-6813	"	Silicone surfactant
Q-25043	Dow Corning	Silicone surfactant
DC-200 (5 cts)	" "	Silicone surfactant
DC-200 (50 cts)	" "	Silicone surfactant
DC-193	" "	Silicone surfactant
	AMINES	
LD-813	Du Pont	Aromatic amines containing 4,4'-methylene bis (2-chloroaniline)
TEOA	U.C.C.	Triethanolamine
A-1	"	70% bis (dimethylamino ethyl ether)/30% DPG
TMBDA	U.C.C.	Tetramethylbutanediamine
A-5	"	Amine mixture
DMEA	"	Dimethylethanolamine
Dabco 8020	Air Products	80% DMEA/20% triethylenediamine
Dabco LV-33	" "	33% triethylenediamine/67% DPG

COMPOUND	SUPPLIER	CHEMICAL STRUCTURE
Dabco DF	" "	Salt of triethylenediamine
Dabco WT	" "	Salt of triethylenediamine
NEM	U.C.C.	N-ethylmorpholine
NMM	"	N-methylmorpholine
Dion Hardener 48	Diamond Shamrock	Mixed aliphatic polyamines

ORGANOTIN CATALYSTS

UL-1	Witco	Dibutyltin bis (dodecylmercaptide)
UL-2	"	Dibutyltin bis (isooctylmaleate)
SUL-4	"	Dibutyltindilaurate
D-22	U.C.C.	Dibutyltindilaurate
T-12	M & T	Dibutyltindilaurate
UL-22		Tin mercaptide

MISCELLANEOUS SOLVENTS

Methylene Chloride	Dow	Methylene Chloride
Isopropanol	U.C.C.	Isopropanol
Butyl Cellosolve	"	Butylether of ethylene glycol
Methyl Cellosolve	"	Methyl ether of ethylene glycol
Cellosolve acetate	"	Acetate of the ethyl ether of ethylene glycol
Trichlorofluoromethane*		Trichlorofluoromethane

* Revised July 1988

APPENDIX B

DATA COLLECTED DURING A SERIES OF 48-HOUR PUMP TESTS CONDUCTED BY THE NEW CASTLE BOARD OF WATER AND LIGHT APRIL-MAY, 1986

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: PH (Potomac Aq. Mon. Point)
245 feet from Production
Well No. 11

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	13.70	Background
	16:15	13.69	
	16:45	12.64	
	17:45	12.59	
	18:15	12.57	
	18:45	12.57	
	19:15	12.58	
	19:45	12.55	
	20.15	12.52	
	20:45	12.54	
4/29/86	06:06	13.37	Start of Test
	06:06:30	13.37	
	06:07	13.46	
	06:08	13.81	
	06:10	14.78	
	06:12	15.69	
	06:14	16.44	
	06:16	17.09	
	06:20	18:14	
	06:26	19.29	
	06:32	20.18	
	06:36	20.66	
	06:46	21.66	
	06:56	22.45	
	07:06	22.96	
	07:16	23.51	
	07:26	23.98	
	07:36	24.41	
	07:46	24.78	
	08:06	25.44	
	08:26	26.00	
	08:46	26.44	
	09:06	26.87	
	09:36	27.23	
	10:06	27.69	
	11:06	28.49	
	12:06	29.14	
	13:06	29.67	
	14:06	30.14	
	15:06	30.52	
	16:06	30.84	
	17:06	31.15	
	18:06	31.35	
	19:06	31.57	
	20:06	31.75	
	21.06	32.00	
	22:06	32.24	
	22:46	32.38	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	00:26	32.75	
	02:06	33.08	
	03:46	33.32	
	05:26	33.50	
	07:06	33.69	
	08:46	33.87	
	10:26	34.08	
	12:06	34.29	
	13:46	34.50	
	15:26	34.66	
	17.06	34.76	
	18.46	34.79	
	20.26	34.86	
	22:06	34.95	
	23:46	35.08	
05/01/86	01:26	35.19	
	03:06	35.29	
	04:46	35.33	
	06:10	34.05	End of Test
05/01/86	06:10	34.05	Recovery Test
	06:10:30	34.04	
	06:11	33.94	
	06:12	33.54	
	06:13	33.08	
	06:14	32.61	
	06:15	31.96	
	06:17	31.38	
	06:19	30.72	
	06:20	30.42	
	06:24	29.40	
	06:30	28.27	
	06:40	26.93	
	06:46	26.32	
	06:50	25.96	
	07:00	25.21	
	07:10	24.57	
	07:20	24.03	
	07:40	23.13	
	07:50	22.75	
	08:30	21.45	
	09:00	20.77	
	09:30	20.20	
	10:30	19.76	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation, New Castle, DE

Station Location: Well No. 29

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	09.36	Background
	16:15	09.35	
	16:45	09.35	
	17:15	--	
	17:45	09.36	
	18:15	09.35	
	18:45	09.35	
	19:24	09.35	
	19:45	09.36	
	20:15	09.35	
	20:45	09.36	
4/29/86	06:06	09.11	Start of Test
	06:06:30	09.38	
	06:07	09.38	
	06:08	09.38	
	06:09	09.38	
	06:10	09.38	
	06:12	09.38	
	06:14	09.38	
	06:16	09.38	
	06:20	09.37	
	06:30	09.37	
	06:40	09.37	
	06:50	09.38	
	07:00	09.37	
	07:20	09.36	
	07:40	09.37	
	07:46	09.37	
	08:06	09.37	
	08:26	09.38	
	08:46	09.35	
	09:06	09.36	
	09:26	09.37	
	09:46	09.36	
	10:06	09.36	
	10:26	09.35	
	10:46	09.37	
	11:06	09.37	
	11:26	09.38	
	11:46	09.36	
	12:06	09.37	
	12.26	09.37	
	12.46	09.34	
	13:06	09.34	
	14:06	09.36	
	15:06	09.34	
	16:06	09.34	
	17:06	09.37	
4/29/86	18:06	09.35	
	19:06	09.32	
	20:06	09.32	
	21:06	09.32	
	22:06	09.33	
	22:46	09.31	
4/30/86	00:26	09.29	
	02:06	09.28	
	03:46	09.27	
	05:26	09.25	
	07:06	09.27	
	08:46	09.26	
	10:26	09.25	
	12:06	09.23	
	13:46	09.21	
	15:26	09.20	
	17:06	09.16	
	18:46	09.12	
	20:26	09.11	
	22:06	09.10	
5/1/86	00:46	09.08	
	01:26	09.08	
	03:06	09.07	
	04:46	09.04	
	06:10	09.11	End of Test
5/1/86	06:11	09.11	Recovery Test
	06:12	09.11	
	06:13	09.11	
	06:15	09.11	
	06:19	09.11	
	06:25	09.11	
	06:29	09.11	
	06:35	09.11	
	06:45	09.11	
	06:55	09.11	
	07:15	09.11	
	07:35	09.12	
	07:49	09.12	
	08:19	09.15	
	08:49	09.13	
	09:19	09.13	
	09:49	09.09	
	09:59	09.16	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 2

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	04:62	Background
	16:15	04.56	
	16:45	04.57	
	17:45	04.57	
	18.15	04.57	
	18:45	04.56	
	19:24	04.57	
	19:45	04.58	
	20:15	04.59	
	20:45	04.59	
4/29/86	06:10:00	04.61	Start of Test
	06:25:15	04.61	
	06:40:30	04.61	
	06:55	04.61	
	07:10	04.61	
	07:25	04.61	
	07:40	04.62	
	07:55	04.62	
	08:10	04.62	
	08:40	04.62	
	09:10	04.62	
	09:40	04.62	
	10:10	04.62	
	10:40	04.62	
	11:10	04.62	
	11:40	04.62	
	12:10	04.61	
	13:10	04.61	
	14:10	04.62	
	15:10	04.61	
	16:10	04.61	
	19:10	04.61	
	18:10	04.59	
	19:10	04.59	
	20:10	04.60	
	21.10	04.62	
	22:10	04.62	
	23:10	04.61	
4/30/86	00:10	04.61	
	01:10	--	
	02:10	04.61	
	03:10	04.64	
	04:10	04.64	
	05:10	04.63	
	06:10	04.63	
	07:10	04.63	
	08:10	04.61	
4/30/86	09:10	04.61	
	10:10	04.61	
	11:10	04.58	
	12:10	04.56	
	13:10	04.56	
	14:10	04.55	
	15:10	04.54	
	16:10	04.52	
	17:10	04.53	
	18:10	04.53	
	19.10	04.51	
	20:10	04.50	
	21:10	04.50	
	22:10	04.49	
	23:10	04.49	
5/1/86	00:10	04.45	
	01:10	04.45	
	02:10	04.47	
	03:10	04.47	
	04:10	04.46	
	05:10	04.44	
	06:10	--	End of Test
5/1/86	06:10	--	Recovery Test
	06:25	04.45	
	06:40	04.43	
	06:55	04.42	
	07:10	04.43	
	07:25	--	
	07:40	04.42	
	07:55	--	
	08:10	04.41	
	08:40	--	
	09:10	04.41	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 4

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	05.93	Background
	16:15	05.94	
	16:45	05.95	
	17:15	--	
	17:45	05.95	
	18:15	05.94	
	18:45	05.94	
	19:24	05.95	
	19:45	05.95	
	20:15	05.95	
	20:45	05.96	
4/29/86	06:10	05.97	Start of Test
	06:25	05.97	
	06:40	05.98	
	06:55	05.97	
	07:10	05.97	
	07:25	05.98	
	07:40	05.98	
	07:55	05.98	
	08:10	--	
	08:40	05.98	
	09:10	05.98	
	09:40	05.99	
	10:10	05.98	
	10:40	05.99	
	11:10	05.99	
	11:40	05.98	
	12:10	05.97	
	13:10	05.98	
	14:10	05.99	
	15:10	05.99	
	16:10	05.99	
	17:10	05.98	
	18:10	05.97	
	19:10	05.98	
	20:10	05.98	
	21:10	06.00	
	22:10	06.01	
	23:10	06.00	
4/30/86	00:10	06.00	
	01:10	--	
	02:10	06.04	
	03:10	06.04	
	04:10	06.04	
	05:10	06.03	
	06:10	06.03	
	07:10	06.03	
	08:10	06.00	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	09:10	06.00	
	10:10	05.99	
	11:10	05.99	
	12:10	05.97	
	13:10	05.97	
	14:10	05.97	
	15:10	05.95	
	16:10	05.95	
	17:10	05.96	
	18:10	05.95	
	19:10	05.94	
	20:10	05.95	
	21:10	05.95	
	22:10	05.93	
	23:10	05.93	
5/1/86	00:10	05.90	
	01:10	05.93	
	02:10	05.92	
	03:10	05.92	
	04:10	05.91	
	05:10	05.91	
	06:10	--	End of Test

AR300772

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 10

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	05.94	
	09:10	05.94	
	09:40	05.95	
	10:10	05.95	
	10:40	05.95	
	11:10	05.95	
	11:40	05.94	
	12:10	05.94	
	13:10	05.94	
	14:10	05.95	
	15:10	05.94	
	16:10	05.94	
	17:10	05.93	
	18:10	05.93	
	19:10	05.93	
	20:10	05.94	
	21:10	05.95	
	22:10	05.97	
	23:10	05.96	
4/30/86	00:10	05.97	
	01:10	--	
	02:10	06.00	
	03:10	06.00	
	04:10	06.00	
	05:10	06.00	
	06:10	05.99	
	07:10	05.99	
	08:10	05.98	
	09:10	05.98	
	10:10	05.97	
	11:10	05.95	
	12:10	05.94	
	13:10	05.95	
	14:10	05.94	
	15:10	05.93	
	16:10	05.92	
	17:10	05.92	
4/30/86	18:10	05.92	
	19:10	05.93	
	20:10	05.92	
	21:10	05.91	
	22:10	05.90	
	23:10	05.91	
5/1/86	00:10	05.88	
	01:10	05.91	
	02:10	05.90	
	03:10	05.90	
	04:10	05.89	
	05:10	05.87	
	06:10	—	End of Test

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 15

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	--	
	09:10	--	
	09:40	--	
	10:10	--	
	10:40	--	
	11:10	--	
	11:40	--	
	12:10	--	
	13:10	07.75	
	14:10	07.74	
	15:10	07.74	
	16:10	07.74	
	17:10	07.74	
	18:10	07.74	
	19:10	07.75	
	20:10	07.75	
	21:10	07.77	
	22:10	07.78	
	23:10	07.77	
4/30/86	00:10	07.77	
	01:10	--	
	02:10	07.81	
	03:10	07.83	
	04:10	07.81	
	05:10	07.81	
	06:10	07.81	
	07:10	07.81	
	08:10	07.79	
	09:10	07.79	
	10:10	07.78	
	11:10	07.77	
	12:10	07.77	
	13:10	07.76	
	14:10	07.75	
	15:10	07.75	
	16:10	07.74	
	17:10	07.74	
4/30/86	18:10	07.76	
	19:10	07.76	
	20:10	07.74	
	21:10	07.75	
	22:10	07.74	
	23:10	07.74	
5/1/86	00:10	07.75	
	01:10	07.73	
	02:10	07.74	
	03:10	07.73	
	04:10	07.73	
	05:10	07.72	
	06:10	--	End of Test

AR300774

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 16

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	--	
	09:10	--	
	09:40	--	
	10:10	--	
	10:40	--	
	11:10	--	
	11:40	--	
	12:10	--	
	13:10	08.29	
	14:10	08.29	
	15:10	08.28	
	16:10	08.28	
	17:10	08.30	
	18:10	08.30	
	19:10	08.29	
	20:10	08.30	
	21:10	08.31	
	22:10	08.31	
	23:10	08.31	
4/30/86	00:10	08.32	
	01:10	--	
	02:10	08.36	
	03:10	08.36	
	04:10	08.34	
	05:10	08.34	
	06:10	08.35	
	07:10	08.36	
	08:10	08.34	
	09:10	08.31	
	10:10	08.32	
	11:10	--	
	12:10	08.31	
	13:10	08.32	
	14:10	08.30	
	15:10	08.30	
	16:10	08.29	
	17:10	08.30	
4/30/86	18:10	08.30	
	19:10	08.30	
	20:10	08.29	
	21:10	08.28	
	22:10	08.28	
	23:10	08.29	
5/1/86	00:10	08.30	
	01:10	08.30	
	02:10	08.30	
	03:10	08.29	
	04:10	08.29	
	05:10	08.29	
	06:10	--	End of Test

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 24

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	04.06	
	09:10	04.06	
	09:40	04.06	
	10:10	04.06	
	10:40	04.06	
	11:10	04.06	
	11:40	04.06	
	12:10	04.05	
	13:10	04.06	
	14:10	04.06	
	15:10	04.05	
	16:10	04.04	
	17:10	04.05	
	18:10	04.04	
	19:10	04.04	
	20:10	04.04	
	21:10	04.05	
	22:10	04.06	
	23:10	04.05	
4/30/86	00:10	04.05	
	01:10	--	
	02:10	04.07	
	03:10	04.06	
	04:10	04.05	
	05:10	04.06	
	06:10	04.07	
	07:10	04.06	
	08:10	04.03	
	09:10	04.04	
	10:10	04.03	
	11:10	04.00	
	12:10	03.99	
	13:10	03.98	
	14:10	03.97	
	15:10	03.96	
	16:10	03.95	
	17:10	03.93	
4/30/86	18:10	03.95	
	19:10	03.93	
	20:10	03.92	
	21:10	03.93	
	22:10	03.91	
	23:10	03.91	
5/1/86	00:10	03.84	
	01:10	03.89	
	02:10	03.88	
	03:10	03.88	
	04:10	03.87	
	05:10	03.87	
	06:10	--	End of Test

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 25

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	03.45	
	09:10	03.46	
	09:40	03.47	
	10:10	03.46	
	10:40	03.46	
	11:10	03.45	
	11:40	03.46	
	12:10	--	
	13:10	03.46	
	14:10	03.45	
	15:10	03.44	
	16:10	03.41	
	17:10	03.41	
	18:10	03.41	
	19:10	03.40	
	20:10	03.40	
	21:10	03.40	
	22:10	03.41	
	23:10	03.39	
4/30/86	00:10	03.37	
	01:10	--	
	02:10	03.41	
	03:10	03.41	
	04:10	03.36	
	05:10	03.36	
	06:10	03.36	
	07:10	03.34	
	08:10	03.31	
	09:10	03.30	
	10:10	03.30	
	11:10	03.27	
	12:10	03.25	
	13:10	03.23	
	14:10	03.22	
	15:10	03.17	
	16:10	03.16	
	17:10	03.15	
4/30/86	18:10	03.16	
	19:10	03.15	
	20:10	03.14	
	21:10	03.12	
	22:10	03.10	
	23:10	03.10	
5/1/86	00:10	03.07	
	01:10	03.06	
	02:10	03.05	
	03:10	03.07	
	04:10	03.03	
	05:10	03.01	
	06:10	--	End of Test
5/1/86	06:25	02.95	Recovery Test
	06:40	02.98	
	06:55	02.97	
	07:10	--	
	07:25	--	
	07:40	02.98	
	07:55	--	
	08:10	02.97	
	08:40	--	
	09:00	02.96	
	09:40	--	
	10:10	--	
	11:10	--	
	12:10	--	
	13:10	--	
	14:10	--	
	15:10	--	
	16:10	--	
	17:10	--	
	18:10	--	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 27

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	06.24	Background
	16:15	--	
	16:45	06.24	
	17:45	06.28	
	18.15	06.30	
	18:45	06.23	
	19:24	06.24	
	19:45	06.26	
	20:15	06.25	
	20:45	06.26	
4/29/86	06:10	06.27	Start of Test
	06:25	06.28	
	06:40	06.31	
	06:55	06.29	
	07:10	06.29	
	07:25	06.29	
	07:40	06.29	
	07:55	06.29	
	08:10	06.29	
	08:40	06.29	
	09:10	06.27	
	09:40	06.28	
	10:10	06.28	
	10:40	06.29	
	11:10	06.29	
	11:40	06.28	
	12:10	06.28	
	13:10	06.28	
	14:10	06.28	
	15:10	06.28	
	16:10	06.27	
	17:10	06.26	
	18:10	06.25	
	19:10	06.25	
	20:10	06.25	
	21.10	06.26	
	22:10	06.26	
	23:10	06.25	
4/30/86	00:10	06.24	
	01:10	--	
	02:10	06.26	
	03:10	06.25	
	04:10	06.26	
	05:10	06.23	
	06:10	06.23	
	07:10	06.21	
	08:10	06.20	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	09:10	06.18	
	10:10	06.16	
	11:10	06.15	
	12:10	06.13	
	13:10	06.12	
	14:10	06.10	
	15:10	06.09	
	16:10	06.07	
	17:10	06.06	
	18:10	06.06	
	19.10	06.04	
	20:10	06.03	
	21:10	06.00	
	22:10	06.00	
	23:10	05.98	
5/1/86	00:10	05.97	
	01:10	05.97	
	02:10	05.95	
	03:10	05.94	
	04:10	05.91	
	05:10	05.90	
	06:10	--	End of Test
5/1/86	06:25	05.88	Recovery Test
	06:40	05.88	
	06:55	05.88	
	07:10	05.88	
	07:25	—	
	07:40	05.87	
	07:55	—	
	08:10	05.87	
	08:40	—	
	09:10	05.85	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 28

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	--	
	09:10	--	
	09:40	--	
	10:10	--	
	10:40	--	
	11:10	--	
	11:40	--	
	12:10	--	
	13:10	--	
	14:10	--	
	15:10	06.47	
	16:10	06.47	
	17:10	06.43	
	18:10	06.41	
	19:10	06.41	
	20:10	06.39	
	21:10	06.38	
	22:10	06.36	
	23:10	06.33	
4/30/86	00:10	06.31	
	01:10	--	
	02:10	06.29	
	03:10	06.31	
	04:10	06.28	
	05:10	06.24	
	06:10	06.24	
	07:10	06.22	
	08:10	06.18	
	09:10	06.25	
	10:10	06.13	
	11:10	06.11	
	12:10	06.08	
	13:10	06.06	
	14:10	06.03	
	15:10	06.01	
	16:10	05.99	
	17:10	05.97	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	18:10	05.96	
	19:10	05.96	
	20:10	05.93	
	21:10	05.91	
	22:10	05.90	
	23:10	05.88	
5/1/86	00:10	05.85	
	01:10	05.85	
	02:10	05.83	
	03:10	05.81	
	04:10	05.79	
	05:10	05.77	
	06:10	--	End of Test
5/1/86	06:25	05.75	Recovery Test
	06:40	05.76	
	06:55	05.75	
	07:10	05.75	
	07:25	--	
	07:40	05.75	
	07:55	--	
	08:10	05.75	
	08:40	--	
	09:10	05.75	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 30

Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	12.50	Background
	16:15	12.50	
	16:45	12.49	
	17:45	12.52	
	18.15	12.49	
	18:45	12.50	
	19:24	12.50	
	19:45	12.52	
	20:15	12.51	
	20:45	12.52	
4/29/86	06:10	12.54	Start of Test
	06:25	12.54	
	06:40	12.55	
	06:55	12.54	
	07:10	12.54	
	07:25	12.55	
	07:40	12.54	
	07:55	12.55	
	08:10	12.55	
	08:40	12.54	
	09:10	12.54	
	09:40	12.55	
	10:10	12.54	
	10:40	12.55	
	11:10	12.54	
	11:40	12.54	
	12:10	12.55	
	13:10	12.54	
	14:10	12.56	
	15:10	12.55	
	16:10	12.54	
	17:10	12.54	
	18:10	12.53	
	19:10	12.53	
	20:10	12.54	
	21.10	12.55	
	22:10	12.56	
	23:10	12.55	
4/30/86	00:10	12.60	
	01:10	--	
	02:10	12.53	
	03:10	12.60	
	04:10	12.61	
	05:10	12.60	
	06:10	12.59	
	07:10	12.60	
	08:10	12.59	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	09:10	12.54	
	10:10	12.55	
	11:10	12.55	
	12:10	12.53	
	13:10	12.53	
	14:10	12.51	
	15:10	12.51	
	16:10	12.50	
	17:10	12.49	
	18:10	12.49	
	19.10	12.48	
	20:10	12.46	
	21:10	12.48	
	22:10	12.46	
	23:10	12.47	
5/1/86	00:10	12.43	
	01:10	12.45	
	02:10	12.45	
	03:10	12.44	
	04:10	12.43	
	05:10	12.42	
	06:10	--	End of Test
5/1/86	06:25	12.42	Recovery Test
	06:40	12.41	
	06:55	12.42	
	07:10	12.41	
	07:25	--	
	07:40	12.40	
	07:55	--	
	08:10	12.41	
	08:40	--	
	09:10	12.38	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 28

Date	Time	Water Level Below M.P. (ft.)	Comments
4/29/86	06:10	--	Start of Test
	06:25	--	
	06:40	--	
	06:55	--	
	07:10	--	
	07:25	--	
	07:40	--	
	07:55	--	
	08:10	--	
	08:40	--	
	09:10	--	
	09:40	--	
	10:10	--	
	10:40	--	
	11:10	--	
	11:40	--	
	12:10	--	
	13:10	--	
	14:10	--	
	15:10	06.47	
	16:10	06.47	
	17:10	06.43	
	18:10	06.41	
	19:10	06.41	
	20:10	06.39	
	21:10	06.38	
	22:10	06.36	
	23:10	06.33	
4/30/86	00:10	06.31	
	01:10	--	
	02:10	06.29	
	03:10	06.31	
	04:10	06.28	
	05:10	06.24	
	06:10	06.24	
	07:10	06.22	
	08:10	06.18	
	09:10	06.25	
	10:10	06.13	
	11:10	06.11	
	12:10	06.08	
	13:10	06.06	
	14:10	06.03	
	15:10	06.01	
	16:10	05.99	
	17:10	05.97	

Date	Time	Water Level Below M.P. (ft.)	Comments
4/30/86	18:10	05.96	
	19:10	05.96	
	20:10	05.93	
	21:10	05.91	
	22:10	05.90	
	23:10	05.88	
5/1/86	00:10	05.85	
	01:10	05.85	
	02:10	05.83	
	03:10	05.81	
	04:10	05.79	
	05:10	05.77	
	06:10	--	End of Test
5/1/86	06:25	05.75	Recovery Test
	06:40	05.76	
	06:55	05.75	
	07:10	05.75	
	07:25	--	
	07:40	05.75	
	07:55	--	
	08:10	05.75	
	08:40	--	
	09:10	05.75	

PUMP TEST ON POTOMAC PRODUCTION WELL NO. 11

Project: Witco Corporation
New Castle, DE

Station Location: Well No. 30

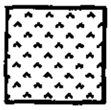
Date	Time	Water Level Below M.P. (ft.)	Comments
4/28/86	15:45	12.50	Background
	16:15	12.50	
	16:45	12.49	
	17:45	12.52	
	18.15	12.49	
	18:45	12.50	
	19:24	12.50	
	19:45	12.52	
	20:15	12.51	
	20:45	12.52	
4/29/86	06:10	12.54	Start of Test
	06:25	12.54	
	06:40	12.55	
	06:55	12.54	
	07:10	12.54	
	07:25	12.55	
	07:40	12.54	
	07:55	12.55	
	08:10	12.55	
	08:40	12.54	
	09:10	12.54	
	09:40	12.55	
	10:10	12.54	
	10:40	12.55	
	11:10	12.54	
	11:40	12.54	
	12:10	12.55	
	13:10	12.54	
	14:10	12.56	
	15:10	12.55	
	16:10	12.54	
	17:10	12.54	
	18:10	12.53	
	19:10	12.53	
	20:10	12.54	
	21.10	12.55	
	22:10	12.56	
	23:10	12.55	
4/30/86	00:10	12.60	
	01:10	--	
	02:10	12.53	
	03:10	12.60	
	04:10	12.61	
	05:10	12.60	
	06:10	12.59	
	07:10	12.60	
	08:10	12.59	
4/30/86	09:10	12.54	
	10:10	12.55	
	11:10	12.55	
	12:10	12.53	
	13:10	12.53	
	14:10	12.51	
	15:10	12.51	
	16:10	12.50	
	17:10	12.49	
	18:10	12.49	
	19.10	12.48	
	20:10	12.46	
	21:10	12.48	
	22:10	12.46	
	23:10	12.47	
5/1/86	00:10	12.43	
	01:10	12.45	
	02:10	12.45	
	03:10	12.44	
	04:10	12.43	
	05:10	12.42	
	06:10	--	End of Test
5/1/86	06:25	12.42	Recovery Test
	06:40	12.41	
	06:55	12.42	
	07:10	12.41	
	07:25	--	
	07:40	12.40	
	07:55	--	
	08:10	12.41	
	08:40	--	
	09:10	12.38	

APPENDIX C

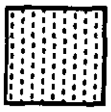
DRILLING LOGS

Symbols Used to Define Various Lithologies:

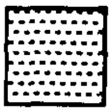
Organic Material (grass, roots etc...) in silty clay matrix.



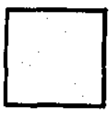
Fill (bricks, slag/resin type material in silty matrix)



Silt



Clay



Sand

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS
Owner: WITCO CHEMICAL CORP.
Location: NEW CASTLE DEL
W.O. Number: 31006-00-01
Soil Boring: B-1
Total Depth: 8.0'
Diameter: 6"
Drilling Company: WALTON CORP.
Drilling Method: H. S. AUGER
Driller: GARY TRUEVER
Log by: R HOOSE
Date Drilled: 3/7/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)	
0		SS-1 (0-2.0)	6,5, 5,5	0 - 0.3'	ORGANIC MATERIAL (grass, roots, etc...) in silty clay matrix
				0.3' - 1.0'	SILTY CLAY, orange brown,
1				1.0' - 1.5'	SILTY CLAY, dark brown,
				1.5' - 1.7'	FILL, dark brown to black, slag and/or yellowish resin type material
2		SS-2 (2.0-4.0)	6,4, 3,2	1.7' - 3.0'	SAND, fine to medium grained with trace fine quartz gravel clasts
3				3.0' - 5.0'	SILTY CLAY, orange brown, moist
4		SS-3 (4.0-6.0)	4,4, 12,11		
5				5.0' - 8.0'	SAND, medium to coarse grained with fine quartz gravel clasts * becomes fine grained and well sorted at 7.8'
6		SS-4 (6.0-8.0)	4,8, 3,2		
7					* encountered water at 7.5'
8					
9					
10					
11					
12					

Environmental Resources Management, Inc.

Drilling Log

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.

Location NEW CASTLE, DEL W.O. Number 31006-00-01

Soil Boring B-2 Total Depth 6.5' Diameter 4"

Sampler CARL PIDGE / R. HOOSE. Drilling Method BUCKET AUGER

Log by CARL PIDGE Date Drilled 3/18/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Description/Soil Classification (color, texture, structure)
0		0 - 1.0' SANDY SILT, yellowish brown, dry
1		1.0' - 1.5' SANDY CLAY, mottled orange brown and dark brown,
		1.5' - 4.5' CLAY, trace fine sand, dark grey with black banding,
2		
3		
4		
		4.5' - 6.5' SAND, dark grey, medium to coarse grained, trace silt from 5.5' - 6.5'
5		
6		
		* encountered water at ~ 6.5'
7		
8		
9		
10		
11		
12		

Environmental Resources Management, Inc.

Drilling Log

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.

Location NEW CASTLE, DEL W.O. Number 31006-00-01

Soil Boring B-3 Total Depth 2.0' Diameter 4"

Sampler CARL PIDGE / JIM WAIT Drilling Method BUCKET AUGER

Log by CARL PIDGE Date Drilled 3/18/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Description/Soil Classification (color, texture, structure)	
0		0 - 0.5'	SILTY CLAY, dark brown
		0.5' - 1.0'	CLAY, tan, moist
1		1.0' - 1.5'	SANDY CLAY, dark tan
		1.5' - 2.0'	SILTY CLAY, grey
2			* encountered water at ~ 2.0'
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS — Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL — W.O. Number: 31006-00-01

Well Number: MW-1 — Total Depth: 31' — Diameter: 2"

Surface Elevation: ____ — Water Level: Initial ____ 24-hours ____

Screen: Dia 2" — Length 5' — Slot Size #20

Casing: Dia 2" — Length 26' — Type PVC SCH 40

Drilling Company: WALTON CORP. — Drilling Method: H.S. AUGER

Driller: GARY TRUEVER — Log by: R. HOOSE — Date Drilled: 3/8/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
0			SS-1 (0-2.0)	2,4, 7,6	0-0.2' ORGANIC MATERIAL (grass, roots etc...) in silty clay matrix
					0.2'-1.5' SILTY CLAY, orange brown, moist
			SS-2 (2.0-4.0)	7,7, 8,8	1.5'-2.0' FILL, slag / resin type material and bricks
					2.0'-5.3' CLAY, orange brown, trace roots and organic material, damp at 3.7'
			SS-3 (4.0-6.0)	1,3, 5,8	
5					5.3'-7.4' SILTY CLAY, mottled light grey and orange brown, micaceous
			SS-4 (6.0-8.0)	3,5, 7,8	7.4'-31.0 SILTY SAND, fine grained, grading to medium grained at 7.6', some fine quartz gravel clasts,
					* encountered water at ~ 8.0'
10					
			SS-5 (13.5-15.5)	3,4, 5,7	SAME
15					
			SS-6 (18.5-20.5)	6,8, 9,11	SAME, becomes rust colored
20					
			SS-7 (23.5-25.5)	4,9, 11,13	SAME
25					

Environmental Resources Management, Inc.

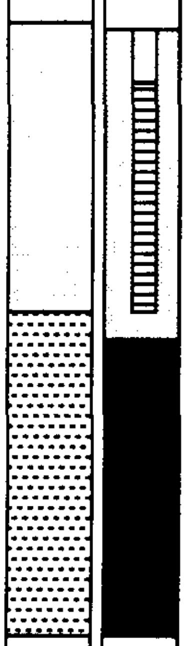
Drilling Log

Project: WITCO RI/FS
Owner: WITCO CHEMICAL CORP.
Location: NEW CASTLE, DEL
W.O. Number: 31006-00-01
Well Number: MW-1
Total Depth: 31'
Diameter: 2"
Surface Elevation:
Water Level: Initial:
24-hours:
Screen: Dia: 2"
Length: 5'
Slot Size: #20
Casing: Dia: 2"
Length: 26'
Type: PVC SCH 40
Drilling Company: WALTON CORP.
Drilling Method: H.S. AUGER
Driller: GARY TRUEVER
Log by: R. HOOSE
Date Drilled: 3/8/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					SAME
30					
					31' CLAY, light grey, very stiff, moist
35					* Drilled to 36', took shelby tube from 36.0' - 38.0'
40					
45					
50					



WELL SPECIFICATIONS

* BOREHOLE BACKFILLED WITH BENTONITE PELLETS FROM 38.0' - 31.5'
# 20 SLOT SCREEN: 31.0' - 26.0'
SAND PACK: 31.5' - 21.5'
BENTONITE SEAL: 21.5' - 19.0'
CEMENT/BENTONITE GROUT TO SURFACE
* WELL COMPLETED WITH 4" ID STEEL PROTECTIVE CASING AND LOCKING CAP.

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS   Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL   W.O. Number: 31006-00-01

Well Number: MW-2   Total Depth: 28'   Diameter: 2"

Surface Elevation: ______   Water Level: Initial ______ 24-hours ______

Screen: Dia 2"   Length 5'   Slot Size #20

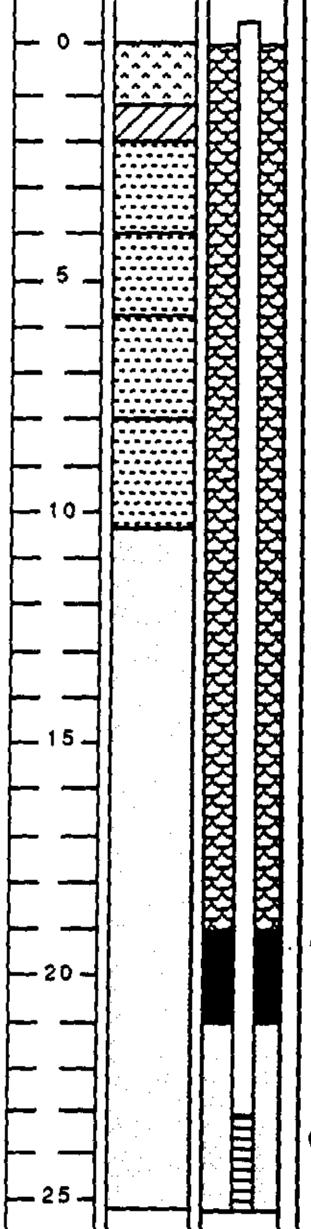
Casing: Dia 2"   Length 23.0'   Type PVC SCH 40

Drilling Company: WALTON CORP.   Drilling Method: H.S. AUGER

Driller: GARY TRUEVER   Log by: R. HOOSE   Date Drilled: 3/9/88

Sketch Map

Notes:



Sample Number	Blow Counts	Depth	Description/Soil Classification (color, texture, structure)
SS-1 (0-2.0)	4,4, 8,6	0-1.1'	ORGANIC MATERIAL (grass, roots etc...) in brown silty clay matrix
		1.1'-2.0'	FILL, bricks, slag / resin type material in brown silty matrix * rusted metallic flakes 1.4'-1.7'
SS-2 (2.0-4.0)	2,4, 6,6	2.0'-4.0'	CLAY, orange brown, dense, moist * encountered water at ~ 3.5'
SS-3 (4.0-6.0)	-,-, -,2	4.0'-5.8'	CLAY, greyish brown, soft, wet
		5.8'-8.0'	SILTY CLAY, mottled orange brown and light grey, stiff
		8.0'10.3'	SANDY CLAY, mottled orange brown and light grey
SS-4 (8.5-10.5)	3,3, 8,16		
		10.3'-25.0'	SAND, medium grained
SS-5 (13.5-15.5)	2,5, 8,12		
SS-6 (18.5-20.5)	8,9, 9,10		SAME, becomes rust colored and coarse with fine quartz gravel clasts
SS-7 (23.5-25.5)	16,8 6,14		

- Indicates Weight of Hammer Advanced Spoon 0.5'

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL W.O. Number: 31006-00-01

Well Number: MW-2 Total Depth: 28' Diameter: 2"

Surface Elevation: ____ Water Level: Initial ____ 24-hours ____

Screen: Dia 2" Length 5' Slot Size #20

Casing: Dia 2" Length 23.0' Type PVC SCH 40

Drilling Company: WALTON CORP. Drilling Method: H.S. AUGER

Driller: GARY TRUEVER Log by: R. HOOSE Date Drilled: 3/9/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					25.0' - 25.4' CLAY, and sand, orange brown, stiff
					25.4' - 28.0' SAND, rust colored, fine grained, well sorted
					28.0' - 30.5' SILTY CLAY, and sand, mottled light and dark grey
			SS-8 (28.5-30.5)	10,12, 12,15	
30					30.5' - 35.0' CLAY, mottled light grey, dark grey and pink / red, with charcoal fragments
			SS-9 (33.5-35.5)	4,5, 10,12	
35					35.0' - 35.5' CLAYEY SILT, and sand, mottled orange and red
					35.5' - 38.2' SAND, mottled light orange brown and light grey to white, very fine grained, well sorted, uniform
			SS-10 (38.2-40.5)	-,2, 7,14	SAME
40					
			SS-11 (43.5-45.5)	12,17, 17,34	SAME
45					
50					

WELL SPECIFICATIONS

* BOREHOLE BACKFILLED WITH BENTONITE PELLETS FROM 43.5'-28.0'
  #20 SLOT SCREEN: 28.0'-23.0'
  SAND PACK: 28.0'-21.0'
  BENTONITE SEAL: 21.0'-19.0'
  CEMENT/BENTONITE GROUT TO SURFACE
* WELL COMPLETED WITH 4" I.D. STEEL PROTECTIVE CASING AND LOCKING CAP

- indicates weight of hammer advanced spoon 0.5'

Environmental Resources Management, Inc.

Drilling Log

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.

Location NEW CASTLE, DEL W.O. Number 31006-00-01

Well Number MW-3 Total Depth 28' Diameter 2"

Surface Elevation ______ Water Level: Initial ______ 24-hours ______

Screen: Dia 2" Length 5' Slot Size #20

Casing: Dia 2" Length 23.0' Type PVC SCH 40

Drilling Company WALTON CORP. Drilling Method H.S. AUGER

Driller GARY TRUEVER Log by R HOOSE Date Drilled 3/10/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
0			SS-1 (0-2.0)	3,4, 7,8	0-1.3' ORGANIC MATERIAL (grass, roots etc...) in brown silty clay matrix
					1.3'-1.8' FILL, mottled dark brown to black (in spots) in silty clay matrix
			SS-2 (2.0-4.0)	5,7, 6,6	1.8'-4.0' SILTY SAND, brown, fine grained,
					4.0'-4.6' SILTY CLAY, orange brown, stiff, moist
5			SS-3 (4.0-6.0)	2,1, 1,1	4.6'-5.5' SILTY SAND, medium grained with fine quartz gravel clasts
			SS-4 (6.0-8.0)	-,1, 1,2	5.5'-5.9' CLAY, orange brown, stiff, moist
					5.9'-25.5' SAND, brown, medium grained with fine quartz gravel clasts
					* Encountered water at ~ 5.8'
10			SS-5 (8.5-10.5)	-,-, 1,-	
15			SS-6 (13.5-15.5)	-,1, 1,1	SAME with trace orange brown clay
20			SS-7 (18.5-20.5)	7,8, 7,11	SAME
25			SS-8 (23.5-25.5)	4,28, 24,15	SAME

- Indicates Weight of Hammer Advanced Spoon 0.5'

AR300792

Environmental Resources Management, Inc. — **Drilling Log**

Project: WITCO RI/FS — Owner: WITCO CHEMICAL CORP.
Location: NEW CASTLE, DEL — W.O. Number: 31006-00-01
Well Number: MW-3 — Total Depth: 28' — Diameter: 2"
Surface Elevation: ______ — Water Level: Initial ______ 24-hours ______
Screen: Dia 2" — Length 5' — Slot Size #20
Casing: Dia 2" — Length 23.0' — Type PVC SCH 40
Drilling Company: WALTON CORP. — Drilling Method: H.S. AUGER
Driller: GARY TRUEVER — Log by: R HOOSE — Date Drilled: 3/10/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					* zone of gneissic clasts from 25.0' - 25.5'
					25.5' - 28.5' SAND, light orange, very fine grained, well sorted, uniform
			SS-9 (28.5-30.5)	4,8, 12,18	28.5' - 33.5' CLAY, mottled light/dark grey and rose colored, stiff, with charcoal fragments
30					
			SS-10 (33.0-33.5)		SAME
35					* Drilled to 33.5', took shelby tube from 33.5' - 35.5'
40					
45					
50					

WELL SPECIFICATIONS

* BOREHOLE BACK FILLED WITH BENTONITE PELLETS FROM 35.5' - 28.5'
  #20 SLOT SCREEN: 28.0' - 23.0'
  SAND PACK: 28.5' - 21.0'
  BENTONITE SEAL: 21.0' - 18.5'
  CEMENT/BENTONITE GROUT TO SURFACE
* WELL COMPLETED WITH 4" I.D. STEEL PROTECTIVE CASING AND LOCKING CAP.

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL W.O. Number: 31006-00-01

Well Number: MW-4 Total Depth: 34' Diameter: 2"

Surface Elevation: ____ Water Level: Initial ____ 24-hours ____

Screen: Dia 2" Length 5' Slot Size #20

Casing: Dia 2" Length 29' Type PVC SCH 40

Drilling Company: WALTON CORP. Drilling Method: H.S. AUGER

Driller: GARY TRUEVER Log by: R HOOSE Date Drilled: 3/11/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
0			SS-1 (0-2.0)	6,4, 5,5	0 - 1.3' ORGANIC MATERIAL (grass, roots etc...) in sandy silt matrix
					1.3' - 1.8' SILTY CLAY, orange brown, stiff
			SS-2 (2.0-4.0)	6,9, 11,14	1.8' - 3.0' CLAYEY SILT, orange brown, stiff
					3.0.' - 4.1' SAND, medium grained, damp
			SS-3 (4.0-6.0)	4,6, 9,11	4.1' - 5.3' CLAY, grey, stiff
5					5.3' - 34.0' SAND, rust colored, medium grained, with fine quartz gravel clasts, micaceous
			SS-4 (6.0-8.0)	5,10, 11,10	
					* encountered water at ~ 7.5'
			SS-5 (8.0-10.0)	4,6, 9,9	
10					
			SS-6 (13.5-15.5)	1,1, 6,9	SAME
15					
			SS-7 (18.5-20.5)	11,11, 13,15	SAME
20					
			SS-8 (23.5-25.5)	6,10, 10,14	SAME
25					

AR300794

Environmental Resources Management, Inc. — **Drilling Log**

Project: WITCO RI/FS — Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL — W.O. Number: 31006-00-01

Well Number: MW-4 — Total Depth: 34' — Diameter: 2"

Surface Elevation: ____ — Water Level: Initial ____ 24-hours ____

Screen: Dia 2" — Length 5' — Slot Size #20

Casing: Dia 2" — Length 29' — Type PVC SCH 40

Drilling Company: WALTON CORP. — Drilling Method: H.S. AUGER

Driller: GARY TRUEVER — Log by: R HOOSE — Date Drilled: 3/11/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					
			SS-9 (28.5-30.5)	7,10, 12,12	SAME, becomes finer grained and greyish brown.
30					
			SS-10 (33.5-35.5)	6,10, 7,10	34.0' - 39.0' CLAY, mottled light and dark grey, stiff, dense * large charcoal fragments at 39.0'
35					
			SS-11 (39.0-39.5)	5	SAME * drilled to 39.5', took shelby tube from 39.5' - 41.5'
40					
45					
50					

WELL SPECIFICATIONS

* BOREHOLE BACKFILLED WITH BENTONITE PELLETS FROM 41.5' - 34.0'
  - #20 SLOT SCREEN: 34.0' - 29.0'
  - SAND PACK: 34.0' - 25.5'
  - BENTONITE SEAL: 25.5' - 22.5'
  - CEMENT/BENTONITE GROUT TO SURFACE
* WELL COMPLETED WITH 4" I.D. STEEL PROTECTIVE CASING AND LOCKING CAP

Environmental Resources Management, Inc.

Drilling Log

Project: WITCO RI/FS Owner: WITCO CHEMICAL CORP.

Location: NEW CASTLE, DEL W.O. Number: 31006-00-01

Well Number: MW-5 Total Depth: 32.5' Diameter: 2"

Surface Elevation: ____ Water Level: Initial ____ 24-hours ____

Screen: Dia 2" Length 5' Slot Size #20

Casing: Dia 2" Length 27.5' Type PVC SCH 40

Drilling Company: WALTON CORP. Drilling Method: H.S. AUGER

Driller: GARY TRUEVER Log by: R. HOOSE Date Drilled: 3/14/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
0					0 -1.0' CONCRETE
			SS-1 (1.0-2.0)	8,7	1.0' - 2.8' FILL, black slag like material in sandy matrix
					2.8' - 3.2' FILL, bricks
			SS-2 (2.0-4.0)	11,12, 15,10	3.2' - 4.0' FILL, black slag / resin type material in sandy matrix
					4.0' - 7.5' SILTY CLAY, yellowish brown, soft, becomes stiff at 6.0'
5			SS-3 (4.0-6.0)	1,2, 1,2	
			SS-4 (6.0-8.0)	1,2, 3,8	7.5' - 29.5' SAND, yellowish to rust colored, fine grained
			SS-5 (8.0-10.0)	7,10, 2,10	* encountered water at ~ 7.8'
10					** Installed 8" I.D. steel casing to 10.0'
			SS-6 (13.5-15.5)	7,4, 6,6	SAME, becoming bluish grey in color
15					
			SS-7 (18.5-20.5)	9,8, 10,12	SAME
20					
			SS-8 (23.5-25.5)	10,9, 12,14	SAME, becoming rust colored
25					

Environmental Resources Management, Inc. **Drilling Log**

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.

Location NEW CASTLE, DEL W.O. Number 31006-00-01

Well Number MW-5 Total Depth 32.5' Diameter 2"

Surface Elevation ______ Water Level:Initial ______ 24-hours ______

Screen: Dia 2" Length 5' Slot Size #20

Casing: Dia 2" Length 27.5' Type PVC SCH 40

Drilling Company WALTON CORP. Drilling Method H.S. AUGER

Driller GARY TRUEVER Log by R HOOSE Date Drilled 3/14/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					
			SS-9 (28.5-30.5)	7,6, 14,14	29.5' - 32.5' **SAND**, mottled white / tan and light orange, fine grained, well sorted, uniform * charcoal fragments at 32.5'
30					
			SS-10 (33.5-35.5)	8,11, 14,18	32.5' - 37.0' **CLAY**, light grey, dense, stiff
35					
			SS-11 (37.0-37.5)	7	**SAME** * Drilled to 37.5', took shelby tube from 37.5' - 39.5'
40					
45					
50					

WELL SPECIFICATIONS

* BOREHOLE BACKFILLED WITH BENTONITE PELLETS FROM 39.5' - 32.5'
  - #20 SLOT SCREEN: 32.0' - 27.0'
  - SAND PACK: 32.5' - 25.4'
  - BENTONITE SEAL: 25.4' - 24.4'
  - CEMENT/BENTONITE GROUT TO SURFACE
* WELL COMPLETED WITH 4" I.D. STEEL PROTECTIVE CASING AND LOCKING CAP

Environmental Resources Management, Inc.

Drilling Log

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.

Location NEW CASTLE, DEL W.O. Number 31006-00-01

Well Number PRODUCTION WELL #1 Total Depth 21' Diameter 6"

Surface Elevation ________ Water Level:Initial ________ 24-hours ________

Screen: Dia 6" Length 11' Slot Size #20

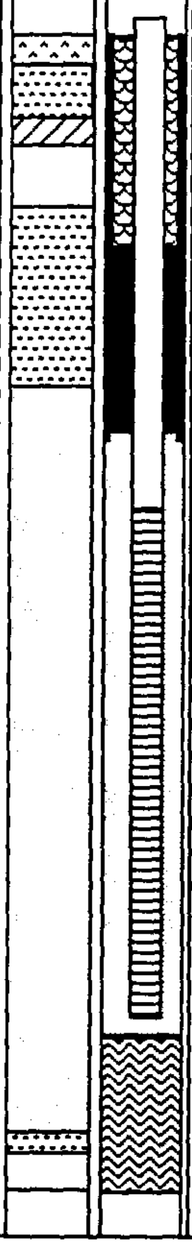
Casing: Dia 6" Length 10' Type PVC SCH 40

Drilling Company WALTON CORP. Drilling Method H.S.A / MUD REAMING

Driller GARY TRUEVER Log by R HOOSE Date Drilled 3/17/88

Sketch Map

Notes:



Depth (feet)	Sample Number	Blow Counts	Interval	Description/Soil Classification (color, texture, structure)
0	SS-1 (0-2.0)	3,4, 4,4	0 - 0.5'	ORGANIC MATERIAL (grass, roots, etc....)
			0.5' - 1.7'	SILTY CLAY, orange brown
	SS-2 (2.0-4.0)	3,3, 3,3	1.7' - 2.2'	FILL, black slag / resin type material in sandy matrix
			2.2' - 3.6'	CLAYEY SAND, medium grained, orange brown, stiff
5	SS-3 (4.0-8.0)	2,2, 2,3	3.6' - 7.5'	SILTY CLAY, orange brown, stiff * encountered water at ~ 6.75'
	SS-4 (6.0-8.0)	4,6, 11,12	7.5' - 25.0'	SAND, rust colored, medium grained with fine quartz gravel clasts * installed 13" I.D. steel casing to 8.75'
10	SS-5 (8.5-10.0)	6,15, 13,15		SAME
15	SS-6 (13.5-15.5)	6,6, 7,8		SAME
20				
	SS-7 (23.5-25.5)	4,5, 9,13		* encountered thin clay layer at 23.8'
25			25.0' - 28.5'	CLAY, mottled light grey and rose color, stiff

Environmental Resources Management, Inc.

Drilling Log

Project WITCO RI/FS Owner WITCO CHEMICAL CORP.
Location NEW CASTLE, DEL W.O. Number 31006-00-01
Well Number PRODUCTION WELL #1 Total Depth 21' Diameter 6"
Surface Elevation ____ Water Level:Initial ____ 24-hours ____
Screen: Dia 6" Length 11' Slot Size #20
Casing: Dia 6" Length 10' Type PVC SCH 40
Drilling Company WALTON CORP. Drilling Method H.S.A / MUD REAMING
Driller GARY TRUEVER Log by R. HOOSE Date Drilled 3/17/88

Sketch Map

Notes:

Depth (feet)	Graphic Log	Well Const.	Sample Number	Blow Counts	Description/Soil Classification (color, texture, structure)
25					
			SS-8 (28.5-30.0)	4,8, 14	SAME
30					* Drilled to 30.0', took shelby tube from 30.0' - 32.0'
35					
40					WELL SPECIFICATIONS * BOREHOLE BACKFILLED WITH BENTONITE PELLETS FROM 32.0' - 27.0' * BOREHOLE CAVED FROM 27.0' - 21.5' #20 SLOT SCREEN: 21.0' - 10.0' SAND PACK: 21.5' - 8.5' BENTONITE SEAL: 8.5' - 4.5' CEMENT/BENTONITE GROUT TO SURFACE * WELL COMPLETED WITH 14" I.D. STEEL PROTECTIVE CASING AND LOCKING CAP
45					
50					

APPENDIX D

SURVEY DATA FOR MONITORING WELLS AT THE NEW CASTLE SPILL SITE

Survey data for monitoring wells at the New Castle Spill Site

Well Number	Elevation			Coordinates	
	Top of Casing	Top of P. V. C	Ground Surface	Northing	Easting
OB-1	9.80	*	8.70	608178.72	459008.19
OB-2	6.40	6.22	6.40	608343.25	458772.65
OB-3	7.20	6.99	7.20	608349.20	459116.68
OB-4	7.77	7.56	7.80	608353.86	459192.21
OB-5	8.57	8.39	8.60	608431.24	459188.97
OB-6	7.96	7.77	8.00	608426.29	459121.58
OB-7	6.99	6.74	7.00	608421.29	459045.88
OB-8	5.93	5.58	5.90	608463.56	459043.13
OB-9	7.10	7.00	7.10	608469.27	459123.02
OB-10	7.65	7.44	7.70	608473.98	459189.36
OB-11	9.47	9.30	9.50	608493.88	459346.85
OB-12	9.90	9.90	9.90	608686.05	459328.49
OB-16	9.43	9.26	9.40	608868.60	459185.08
OB-21	8.49	8.28	8.50	608695.83	459065.34
OB-22	7.30	**	7.30	608593.76	458996.02
OB-24	5.70	5.54	5.70	608452.03	458960.64
OB-25	5.16	5.16	5.20	608332.27	458895.25
PH	9.14	9.14	7.20	608193.15	458835.22
OB-27	8.18	8.00	8.20	608188.94	458882.93
OB-28	8.46	8.28	8.50	607978.74	458685.80
OB-29	11.15	11.13	11.20	607956.26	458868.11
OB-30	14.50	14.33	14.50	607983.12	459042.03
M.W. #1		10.57	8.60	608432.36	459200.84
M.W. #2		7.89	5.80	608452.30	458975.19
M.W. #3		9.09	7.10	608349.59	459100.06
M.W. #4		10.51	8.40	608175.64	458893.37
M.W. #5		11.19	9.10	608543.95	459070.31
P.W. #1		8.89	7.10	608457.19	459079.47

* No PVC interior pipe present

** Well damaged, filled with stones

APPENDIX E

DATA COLLECTED DURING THE 24-HOUR PUMP TEST
12-13 MAY 1988

APPENDIX E

DATA COLLECTED DURING THE 24-HOUR PUMP TEST
12-13 MAY 1988

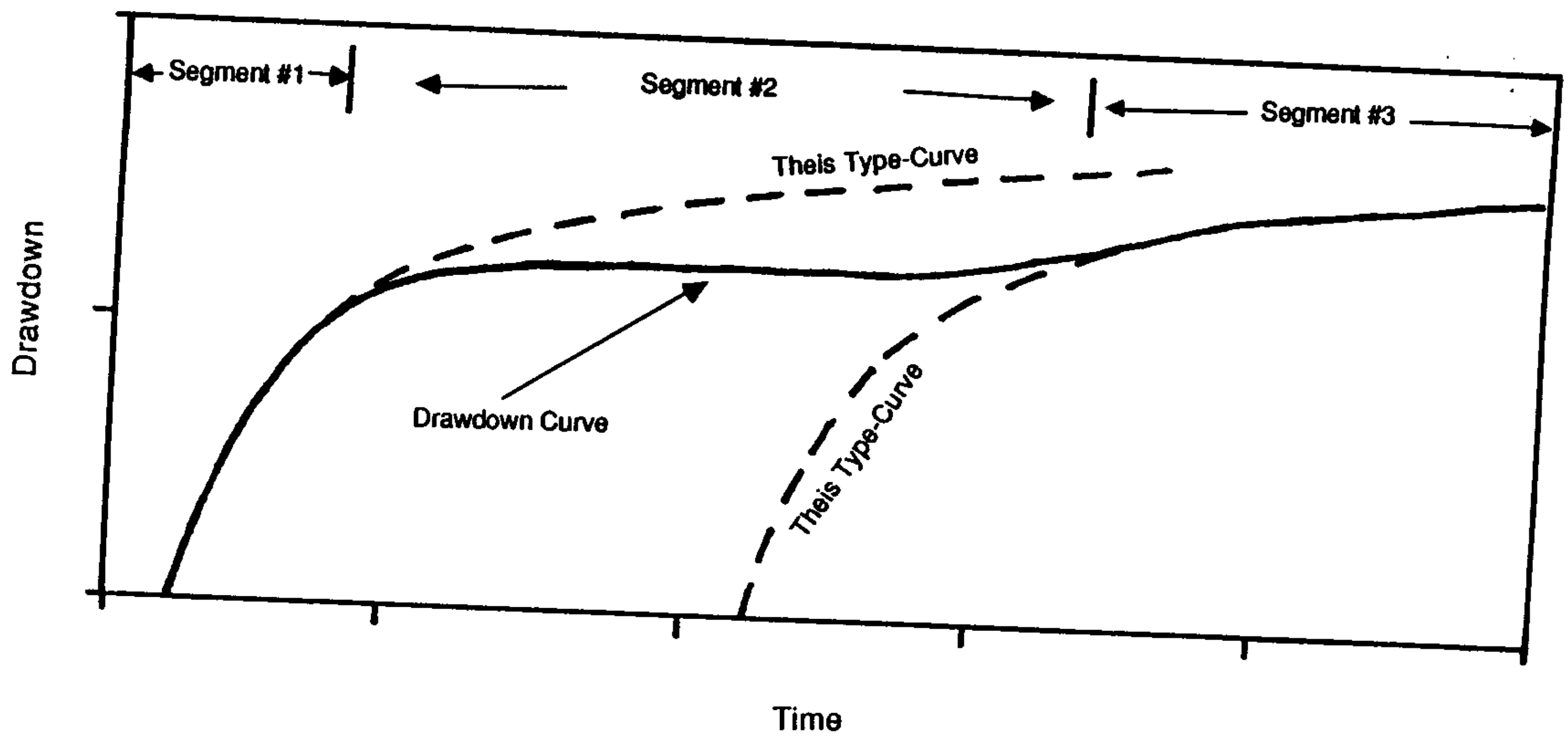
The primary objective of conducting the 24-hour test was to 1) estimate the transmissivity of the Columbia Aquifer within the study area; and 2) evaluate the area influenced by pumping. The data collected and results of the pump test analysis will be used in the evaluation of remedial alternatives during the feasibility study phase of the project.

Selection of a Method of Data Analysis

Consideration has been given to an appropriate method of analyzing the data obtained from the 24-hour test. The criteria in method selection was to use an analysis method that is both valid, with respect to the hydrogeologic model, and achieves the goals of the test. Consideration was given to analyzing the data by the Boulton Method for an unconfined aquifer.

The Boulton Method defines three segments of the time-drawdown curve as depicted in Figure E-1. In the first segment, the time-drawdown curve indicates that the response to pumping is equivalent to that of a confined aquifer. Water is released from storage by both compaction of the aquifer matrix, and by expansion of the water. This initial segment of the Boulton curve follows the Theis type-curve. Consequently, the aquifer transmissivity can be calculated by the Theis Method in this first segment. In the second segment, the time-drawdown curve deviates from the Theis type-curve as a result of gravity

Figure E-1
Drawdown Data From an Observation Well in an Unconfined Aquifer Showing Delayed Yield



drainage (delayed yield) of the inter-granular porosity in the aquifer. Effectively, the aquifer storage coefficient is in transition from confined to unconfined conditions. In the third segment, the time-drawdown curve again follows the Theis type-curve (Kruseman and DeRidder, 1983). However, the second Theis curve is shifted to the right, reflecting a new, larger storage coefficient. Transmissivity calculated from this third segment should equal transmissivity calculated from the first segment.

Figure E-2 presents a Theis plot of well OB-3 with the Theis type-curve overlain. Data collected from well OB-3 during the pump test closely follow the type-curve. Additionally, the data does not indicate that a delayed yield deviation from the confined type-curve has occurred by the end of the 24-hour test. The data resulting from the pump test is still within the first segment of the time-drawdown curve described by Boulton. It is likely that if pumping had continued for a longer time, delayed yield deviations would have occurred. The Boulton Method could then be applied to determine a delayed yield factor. However, given the existing data set, the Theis Method is an appropriate method of determining transmissivity from the pump test data.

Validity of the Cooper-Jacob Method

The Cooper-Jacob Method (Jacob Method) is based on the fact that the Theis Type-Curve plotted semi-logarithmically, with $W(u)$ on the arithmetic Y-Axis and $1/u$ on the logarithmic X-Axis, yields a straight line for values of $u \leq 0.01$ ($1/u \geq 100$) (Figure E-3). This straight line portion of the semi-logarithmic type-curve is where the Jacob Method becomes valid.

Figure E-2
Pump Test Data From Well OB-3
With Theis Type-Curve

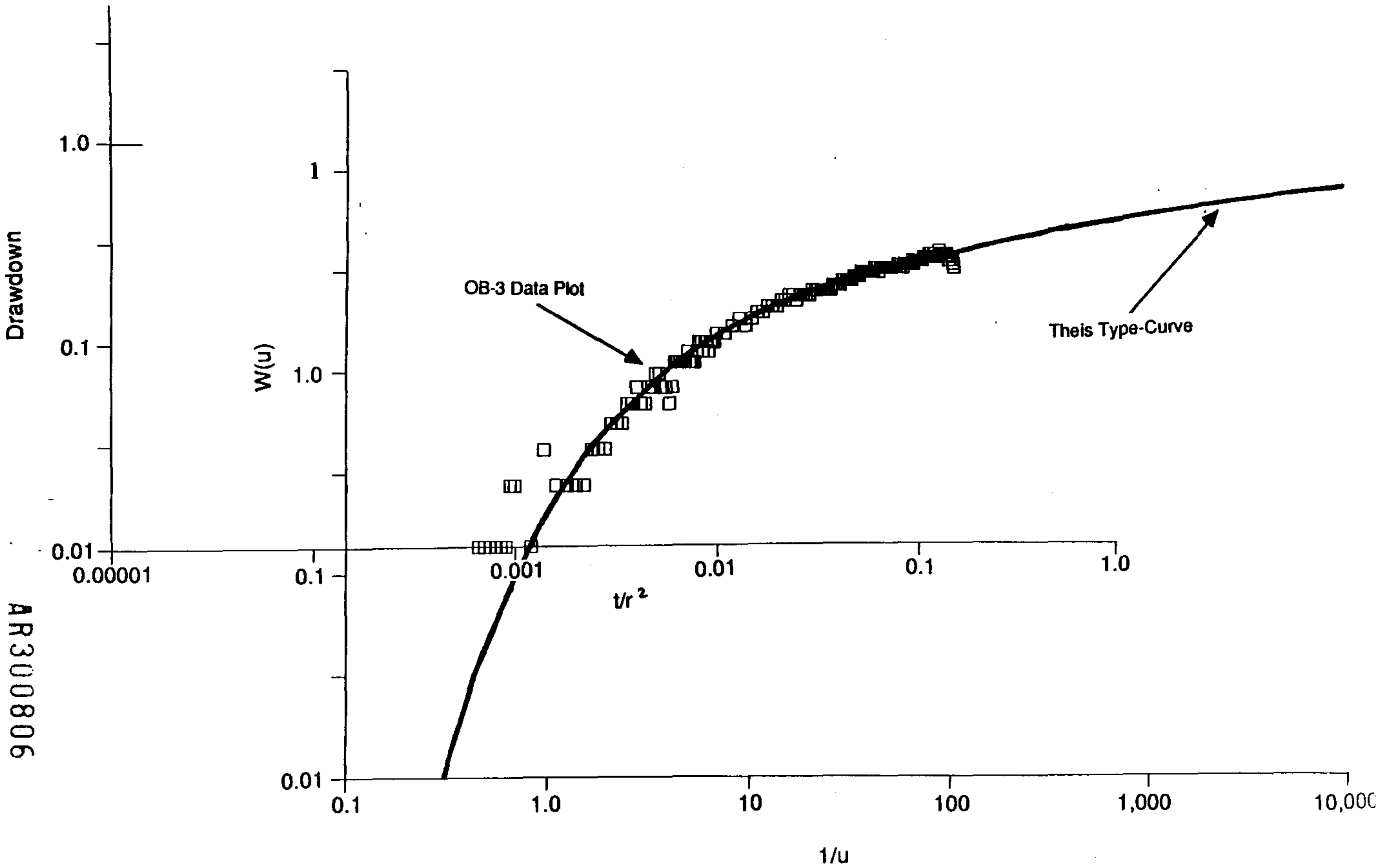
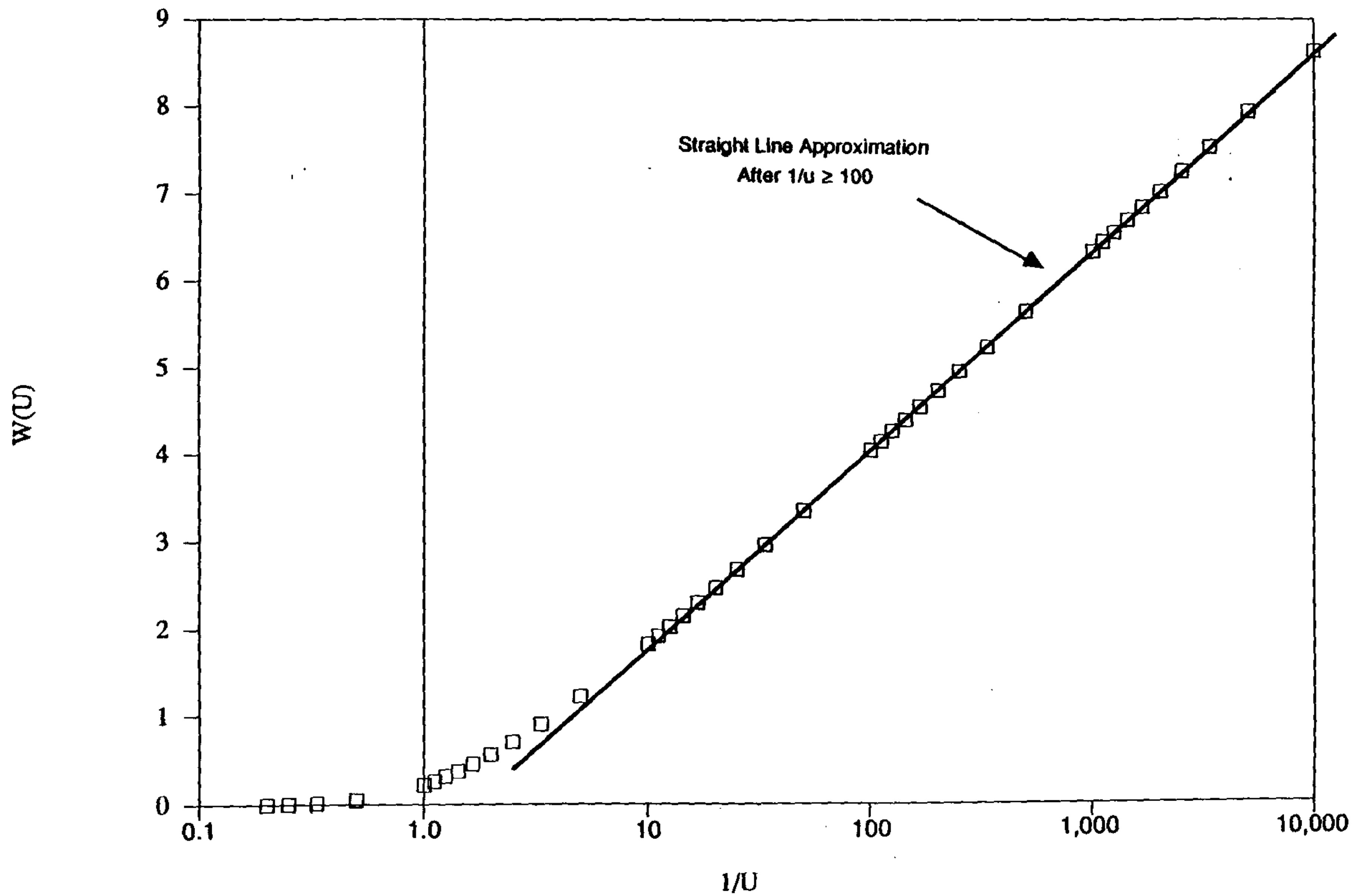


Figure E-3
Jacob Straight Line Plot of Theis Type-Curve
After 1/u ≥ 100



AR300807

By re-arranging the equation that defines u, the time at which the Jacob Method becomes valid for a given pumping scenario can be calculated:

$$u = \frac{r^2 s}{4Tt}$$

Where:

r = Radial distance to pumping well

s = Aquifer storativity

T = Aquifer transmissivity

t = Time

$$t = \frac{r^2 s}{4Tu}$$

For instance, if: r = 50 ft., s = 0.02, T = 50,000 gpd/ft (6,685 ft^2/d) and u = 0.01, then:

$$t = \frac{r^2 s}{4Tt} = \frac{(50^2)\ (0.02)}{4\ (6{,}685)(0.01)}$$

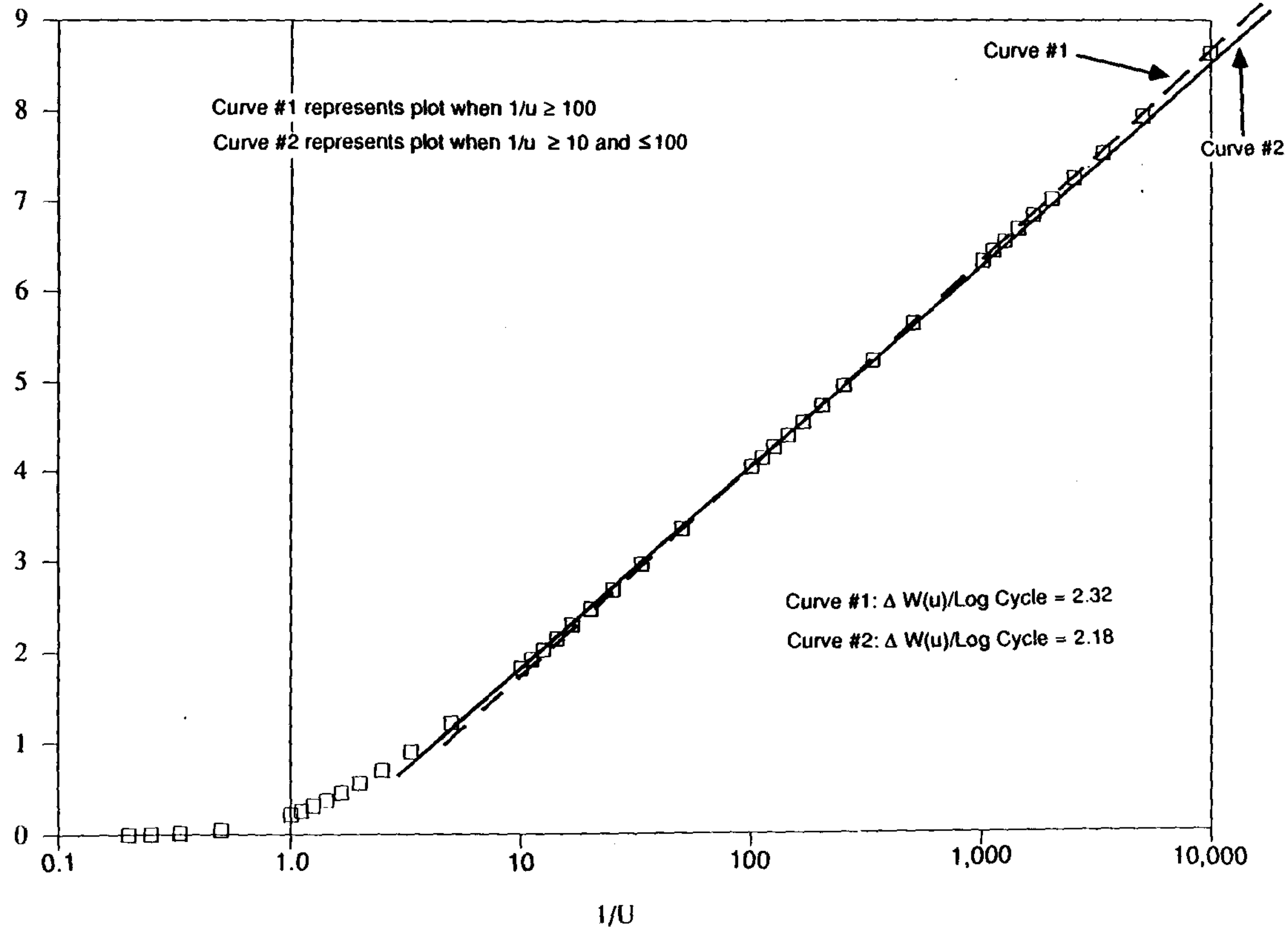
t = 0.2 days = 300 min.

The t of 300 minutes is the time after which application of the Jacob Method in this particular example is valid.

Close inspection of the semi-logarithmic type-curve presented in Figure E-3 reveals that the type-curve deviates from the straight line only slightly after 1/u = 10. This suggests that the Jacob Method is valid, with a small degree of error when $1/u \geq 10$ ($u \leq 0.1$). This error can be calculated from the slopes of the two curves presented in Figure E-4.

ure E-4

Jacob Straight Line Plot of Theis Type-Curve Showing Deviation Between $1/u \geq 10$ and ≤ 100, and $1/u \geq 100$



The straight line portion of the type curve is given by Curve Number 1, while Curve Number 2 represents the deviation between $1/u \geq 10$ and $1/u \leq 100$. The percent error is calculated by determining the slope of both curves and inputting these slopes into the following equation:

$$\% \text{ Error} = \left[\frac{(\text{Slope Curve No. 1} - \text{Slope Curve No. 2})}{\text{Slope Curve No. 1}}\right] X\ 100$$

The slopes of Curves Number 1 and Number 2 are 2.32 and 2.18, respectively. Inputting these data into the aforementioned equation yields an error of 6 percent. ERM considers this to be a small amount of error with respect to the range of transmissivities typically determined from data analysis. Therefore, in analyzing the data from this pump test, data was considered valid after $1/u \geq 10$ ($u \leq 0.1$).

Water Levels Obtained from Hermit Data Loggers During 24 Hour Pump Test

MW-1									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0.0000	9.56	7.00	9.56	170.00	9.65	750.00	9.50	1330.00	9.68
0.0033	9.31	7.50	9.59	180.00	9.65	760.00	9.50	1340.00	9.72
0.0066	9.27	8.00	9.56	190.00	9.65	770.00	9.50	1350.00	9.72
0.0099	9.27	8.50	9.59	200.00	9.65	780.00	9.50	1360.00	9.72
0.0133	9.27	9.00	9.59	210.00	9.65	790.00	9.50	1370.00	9.72
0.0166	9.27	9.50	9.59	220.00	9.65	800.00	9.50	1380.00	9.68
0.0200	9.27	10.00	9.59	230.00	9.65	810.00	9.50	1390.00	9.72
0.0233	9.27	12.00	9.59	240.00	9.65	820.00	9.50	1400.00	9.68
0.0266	9.27	14.00	9.59	250.00	9.65	830.00	9.50	1410.00	9.72
0.0300	9.27	16.00	9.59	260.00	9.65	840.00	9.50	1420.00	9.68
0.0333	9.27	18.00	9.59	270.00	9.65	850.00	9.50	1430.00	9.68
0.0500	9.53	20.00	9.59	280.00	9.65	860.00	9.50	1440.00	9.68
0.0666	9.53	22.00	9.59	290.00	9.65	870.00	9.50	1450.00	9.68
0.0833	9.53	24.00	9.59	300.00	9.65	880.00	9.50	1460.00	9.68
0.1000	9.53	26.00	9.59	310.00	9.65	890.00	9.50	1470.00	9.68
0.1166	9.53	28.00	9.59	320.00	9.65	900.00	9.50	1480.00	9.68
0.1333	9.53	30.00	9.59	330.00	9.62	910.00	9.46	1490.00	9.68
0.1500	9.53	32.00	9.59	340.00	9.62	920.00	9.50	1500.00	9.65
0.1666	9.53	34.00	9.59	350.00	9.62	930.00	9.50		
0.1833	9.53	36.00	9.59	360.00	9.62	940.00	9.50		
0.2000	9.53	38.00	9.62	370.00	9.59	950.00	9.46		
0.2166	9.53	40.00	9.62	380.00	9.59	960.00	9.50		
0.2333	9.53	42.00	9.62	390.00	9.59	970.00	9.50		
0.2500	9.53	44.00	9.59	400.00	9.56	980.00	9.50		
0.2666	9.53	46.00	9.62	410.00	9.56	990.00	9.50		
0.2833	9.53	48.00	9.62	420.00	9.56	1000.00	9.50		
0.3000	9.53	50.00	9.62	430.00	9.53	1010.00	9.50		
0.3166	9.53	52.00	9.62	440.00	9.53	1020.00	9.50		
0.3333	9.53	54.00	9.62	450.00	9.53	1030.00	9.50		
0.4167	9.56	56.00	9.62	460.00	9.53	1040.00	9.50		
0.5000	9.56	58.00	9.62	470.00	9.53	1050.00	9.50		
0.5833	9.56	60.00	9.62	480.00	9.53	1060.00	9.50		
0.6667	9.56	62.00	9.62	490.00	9.50	1070.00	9.50		
0.7500	9.56	64.00	9.62	500.00	9.50	1080.00	9.53		
0.8333	9.56	66.00	9.62	510.00	9.50	1090.00	9.53		
0.9167	9.56	68.00	9.62	520.00	9.50	1100.00	9.53		
1.00	9.56	70.00	9.62	530.00	9.50	1110.00	9.53		
1.08	9.56	72.00	9.62	540.00	9.50	1120.00	9.56		
1.17	9.56	74.00	9.62	550.00	9.50	1130.00	9.56		
1.25	9.56	76.00	9.62	560.00	9.50	1140.00	9.56		
1.33	9.56	78.00	9.65	570.00	9.50	1150.00	9.59		
1.42	9.56	80.00	9.62	580.00	9.50	1160.00	9.59		
1.50	9.56	82.00	9.65	590.00	9.50	1170.00	9.59		
1.58	9.56	84.00	9.65	600.00	9.50	1180.00	9.62		
1.67	9.56	86.00	9.65	610.00	9.50	1190.00	9.62		
1.75	9.56	88.00	9.65	620.00	9.50	1200.00	9.62		
1.83	9.56	90.00	9.65	630.00	9.50	1210.00	9.62		
1.92	9.56	92.00	9.65	640.00	9.50	1220.00	9.65		
2.00	9.56	94.00	9.62	650.00	9.50	1230.00	9.65		
2.50	9.56	96.00	9.65	660.00	9.50	1240.00	9.65		
3.00	9.56	98.00	9.65	670.00	9.50	1250.00	9.65		
3.50	9.56	100.00	9.65	680.00	9.50	1260.00	9.65		
4.00	9.56	110.00	9.65	690.00	9.50	1270.00	9.68		
4.50	9.56	120.00	9.65	700.00	9.50	1280.00	9.68		
5.00	9.56	130.00	9.65	710.00	9.50	1290.00	9.68		
5.50	9.56	140.00	9.65	720.00	9.50	1300.00	9.68		
6.00	9.56	150.00	9.65	730.00	9.50	1310.00	9.68		
6.50	9.56	160.00	9.65	740.00	9.50	1320.00	9.68		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained from Hermit Data Loggers During 24 Hour Pump Test

MW - 2									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0	6.85	7.00	6.93	170.00	7.13	750.00	7.21	1330.00	7.24
0.0033	6.85	7.50	6.94	180.00	7.14	760.00	7.21	1340.00	7.24
0.0066	6.85	8.00	6.94	190.00	7.14	770.00	7.21	1350.00	7.24
0.0099	6.85	8.50	6.94	200.00	7.15	780.00	7.21	1360.00	7.23
0.0133	6.86	9.00	6.95	210.00	7.15	790.00	7.21	1370.00	7.23
0.0166	6.86	9.50	6.94	220.00	7.15	800.00	7.21	1380.00	7.23
0.02	6.86	10.00	6.95	230.00	7.15	810.00	7.21	1390.00	7.24
0.0233	6.85	12.00	6.97	240.00	7.16	820.00	7.21	1400.00	7.23
0.0266	6.86	14.00	6.99	250.00	7.16	830.00	7.21	1410.00	7.23
0.03	6.86	16.00	6.99	260.00	7.15	840.00	7.21	1420.00	7.23
0.0333	6.86	18.00	6.99	270.00	7.15	850.00	7.21	1430.00	7.22
0.05	6.85	20.00	7.01	280.00	7.15	860.00	7.21	1440.00	7.23
0.0666	6.86	22.00	7.01	290.00	7.16	870.00	7.21	1450.00	7.23
0.0833	6.86	24.00	7.02	300.00	7.16	880.00	7.21	1460.00	7.22
0.1	6.85	26.00	7.02	310.00	7.15	890.00	7.21	1470.00	7.22
0.1166	6.85	28.00	7.03	320.00	7.16	900.00	7.21	1480.00	7.22
0.1333	6.86	30.00	7.04	330.00	7.16	910.00	7.21	1490.00	7.13
0.15	6.86	32.00	7.04	340.00	7.16	920.00	7.21	1500.00	7.07
0.1666	6.86	34.00	7.04	350.00	7.15	930.00	7.21	1510.00	7.05
0.1833	6.86	36.00	7.06	360.00	7.15	940.00	7.21		
0.2	6.86	38.00	7.06	370.00	7.16	950.00	7.22		
0.2166	6.86	40.00	7.05	380.00	7.16	960.00	7.21		
0.2333	6.86	42.00	7.06	390.00	7.16	970.00	7.22		
0.25	6.86	44.00	7.06	400.00	7.16	980.00	7.22		
0.2666	6.86	46.00	7.07	410.00	7.17	990.00	7.22		
0.2833	6.86	48.00	7.07	420.00	7.17	1000.00	7.23		
0.3	6.86	50.00	7.07	430.00	7.17	1010.00	7.23		
0.3166	6.86	52.00	7.08	440.00	7.17	1020.00	7.23		
0.3333	6.86	54.00	7.07	450.00	7.17	1030.00	7.22		
0.4167	6.86	56.00	7.07	460.00	7.17	1040.00	7.23		
0.5	6.86	58.00	7.08	470.00	7.18	1050.00	7.23		
0.5833	6.86	60.00	7.07	480.00	7.18	1060.00	7.23		
0.6667	6.86	62.00	7.07	490.00	7.18	1070.00	7.23		
0.75	6.87	64.00	7.08	500.00	7.18	1080.00	7.23		
0.8333	6.87	66.00	7.09	510.00	7.18	1090.00	7.24		
0.9167	8.87	68.00	7.09	520.00	7.19	1100.00	7.24		
1.00	6.87	70.00	7.09	530.00	7.19	1110.00	7.24		
1.08	6.87	72.00	7.09	540.00	7.19	1120.00	7.24		
1.17	6.87	74.00	7.09	550.00	7.19	1130.00	7.25		
1.25	6.87	76.00	7.09	560.00	7.19	1140.00	7.25		
1.33	6.88	78.00	7.09	570.00	7.19	1150.00	7.25		
1.42	6.88	80.00	7.09	580.00	7.19	1160.00	7.25		
1.50	6.88	82.00	7.09	590.00	7.19	1170.00	7.24		
1.58	6.88	84.00	7.09	600.00	7.20	1180.00	7.25		
1.67	6.88	86.00	7.10	610.00	7.20	1190.00	7.24		
1.75	6.88	88.00	7.09	620.00	7.20	1200.00	7.24		
1.83	6.88	90.00	7.10	630.00	7.20	1210.00	7.25		
1.92	6.88	92.00	7.10	640.00	7.20	1220.00	7.25		
2.00	6.88	94.00	7.10	650.00	7.20	1230.00	7.25		
2.50	6.89	96.00	7.10	660.00	7.20	1240.00	7.24		
3.00	6.89	98.00	7.11	670.00	7.20	1250.00	7.24		
3.50	6.89	100.00	7.11	680.00	7.20	1260.00	7.23		
4.00	6.90	110.00	7.11	690.00	7.20	1270.00	7.25		
4.50	6.91	120.00	7.12	700.00	7.21	1280.00	7.24		
5.00	6.91	130.00	7.12	710.00	7.21	1290.00	7.24		
5.50	6.92	140.00	7.12	720.00	7.21	1300.00	7.24		
6.00	6.92	150.00	7.12	730.00	7.20	1310.00	7.24		
6.50	6.92	160.00	7.14	740.00	7.20	1320.00	7.24		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained from Hermit Data Loggers During 24 Hour Pump Test

MW - 3									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0	7.97	6.50	8.11	150.00	8.11	720.00	8.16	1290.00	8.21
0.0033	7.99	7.00	8.11	160.00	8.13	730.00	8.16	1300.00	8.21
0.0066	7.99	7.50	8.11	170.00	8.13	740.00	8.16	1310.00	8.21
0.0099	7.99	8.00	8.11	180.00	8.13	750.00	8.16	1320.00	8.23
0.0133	7.99	8.50	8.11	190.00	8.15	760.00	8.16	1330.00	8.21
0.0166	8.00	9.00	8.11	200.00	8.15	770.00	8.18	1340.00	8.21
0.02	8.00	9.50	8.13	210.00	8.15	780.00	8.16	1350.00	8.21
0.0233	8.00	10.00	8.11	220.00	8.16	790.00	8.16	1360.00	8.21
0.0266	8.00	12.00	8.11	230.00	8.16	800.00	8.16	1370.00	8.21
0.03	8.00	14.00	8.11	240.00	8.16	810.00	8.16	1380.00	8.21
0.0333	8.00	16.00	8.08	250.00	8.15	820.00	8.16	1390.00	8.21
0.05	8.00	18.00	8.07	260.00	8.15	830.00	8.16	1400.00	8.19
0.0666	8.00	20.00	8.07	270.00	8.16	840.00	8.16	1410.00	8.19
0.0833	8.00	22.00	8.05	280.00	8.15	850.00	8.16	1420.00	8.19
0.1	8.00	24.00	8.05	290.00	8.16	860.00	8.16	1430.00	8.19
0.1166	8.00	26.00	8.04	300.00	8.16	870.00	8.18	1440.00	8.19
0.1333	8.00	28.00	8.04	310.00	8.16	880.00	8.16	1450.00	8.19
0.15	8.02	30.00	8.05	320.00	8.15	890.00	8.16	1460.00	8.19
0.1666	8.02	32.00	8.05	330.00	8.15	900.00	8.16	1470.00	8.19
0.1833	8.00	34.00	8.05	340.00	8.15	910.00	8.16	1480.00	8.18
0.2	8.02	36.00	8.05	350.00	8.13	920.00	8.16	1490.00	8.16
0.2166	8.02	38.00	8.05	360.00	8.15	930.00	8.16	1500.00	8.15
0.2333	8.02	40.00	8.05	370.00	8.13	940.00	8.18		
0.25	8.02	42.00	8.05	380.00	8.13	950.00	8.16		
0.2666	8.02	44.00	8.07	390.00	8.13	960.00	8.16		
0.2833	8.02	46.00	8.07	400.00	8.15	970.00	8.16		
0.3	8.02	48.00	8.07	410.00	8.13	980.00	8.16		
0.3166	8.02	50.00	8.07	420.00	8.15	990.00	8.18		
0.3333	8.02	52.00	8.08	430.00	8.15	1000.00	8.18		
0.4167	8.02	54.00	8.07	440.00	8.13	1010.00	8.18		
0.5	8.02	56.00	8.07	450.00	8.15	1020.00	8.18		
0.5833	8.04	58.00	8.07	460.00	8.15	1030.00	8.18		
0.6667	8.04	60.00	8.07	470.00	8.15	1040.00	8.18		
0.75	8.05	62.00	8.08	480.00	8.15	1050.00	8.18		
0.8333	8.05	64.00	8.08	490.00	8.15	1060.00	8.18		
0.9167	8.05	66.00	8.08	500.00	8.15	1070.00	8.18		
1.00	8.05	68.00	8.08	510.00	8.15	1080.00	8.18		
1.08	8.05	70.00	8.08	520.00	8.15	1090.00	8.19		
1.17	8.05	72.00	8.10	530.00	8.15	1100.00	8.19		
1.25	8.07	74.00	8.10	540.00	8.16	1110.00	8.19		
1.33	8.07	76.00	8.10	550.00	8.16	1120.00	8.19		
1.42	8.07	78.00	8.10	560.00	8.15	1130.00	8.21		
1.50	8.07	80.00	8.10	570.00	8.16	1140.00	8.21		
1.58	8.07	82.00	8.10	580.00	8.16	1150.00	8.21		
1.67	8.08	84.00	8.11	590.00	8.16	1160.00	8.21		
1.75	8.08	86.00	8.11	600.00	8.16	1170.00	8.19		
1.83	8.08	88.00	8.11	610.00	8.16	1180.00	8.21		
1.92	8.08	90.00	8.11	620.00	8.16	1190.00	8.21		
2.00	8.08	92.00	8.10	630.00	8.16	1200.00	8.21		
2.50	8.10	94.00	8.11	640.00	8.16	1210.00	8.21		
3.00	8.10	96.00	8.11	650.00	8.16	1220.00	8.21		
3.50	8.10	98.00	8.10	660.00	8.16	1230.00	8.21		
4.00	8.10	100.00	8.13	670.00	8.16	1240.00	8.21		
4.50	8.11	110.00	8.11	680.00	8.16	1250.00	8.21		
5.00	8.11	120.00	8.11	690.00	8.16	1260.00	8.21		
5.50	8.11	130.00	8.11	700.00	8.16	1270.00	8.21		
6.00	8.11	140.00	8.11	710.00	8.16	1280.00	8.21		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hermit Data Loggers During 24 Hour Pump Test

OB - 3									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW*	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0.0000	5.86	7.00	5.87	170.00	6.00	750.00	6.09	1330.00	6.13
0.0033	5.86	7.50	5.87	180.00	6.01	760.00	6.09	1340.00	6.13
0.0066	5.86	8.00	5.87	190.00	6.01	770.00	6.09	1350.00	6.13
0.0099	5.86	8.50	5.87	200.00	6.01	780.00	6.09	1360.00	6.13
0.0133	5.87	9.00	5.87	210.00	6.02	790.00	6.10	1370.00	6.12
0.0166	5.87	9.50	5.88	220.00	6.02	800.00	6.10	1380.00	6.13
0.0200	5.87	10.00	5.88	230.00	6.03	810.00	6.09	1390.00	6.12
0.0233	5.87	12.00	5.87	240.00	6.03	820.00	6.10	1400.00	6.12
0.0266	5.87	14.00	5.89	250.00	6.02	830.00	6.10	1410.00	6.12
0.0300	5.87	16.00	5.88	260.00	6.03	840.00	6.09	1420.00	6.11
0.0333	5.87	18.00	5.88	270.00	6.03	850.00	6.10	1430.00	6.11
0.0500	5.87	20.00	5.88	280.00	6.03	860.00	6.10	1440.00	6.12
0.0666	5.87	22.00	5.88	290.00	6.03	870.00	6.10	1450.00	6.12
0.0833	5.87	24.00	5.89	300.00	6.04	880.00	6.10	1460.00	6.12
0.1000	5.87	26.00	5.89	310.00	6.04	890.00	6.10	1470.00	6.12
0.1166	5.87	28.00	5.89	320.00	6.04	900.00	6.10	1480.00	6.11
0.1333	5.87	30.00	5.90	330.00	6.04	910.00	6.10	1490.00	6.10
0.1500	5.87	32.00	5.90	340.00	6.04	920.00	6.10	1500.00	6.09
0.1666	5.87	34.00	5.90	350.00	6.04	930.00	6.10		
0.1833	5.87	36.00	5.91	360.00	6.04	940.00	6.11		
0.2000	5.87	38.00	5.91	370.00	6.04	950.00	6.10		
0.2166	5.87	40.00	5.92	380.00	6.05	960.00	6.11		
0.2333	5.87	42.00	5.91	390.00	6.05	970.00	6.11		
0.2500	5.87	44.00	5.91	400.00	6.05	980.00	6.11		
0.2666	5.87	46.00	5.92	410.00	6.05	990.00	6.11		
0.2833	5.87	48.00	5.92	420.00	6.06	1000.00	6.11		
0.3000	5.87	50.00	5.93	430.00	6.06	1010.00	6.11		
0.3166	5.87	52.00	5.93	440.00	6.06	1020.00	6.11		
0.3333	5.87	54.00	5.92	450.00	6.06	1030.00	6.11		
0.4167	5.87	56.00	5.92	460.00	6.06	1040.00	6.11		
0.5000	5.87	58.00	5.91	470.00	6.06	1050.00	6.11		
0.5833	5.87	60.00	5.92	480.00	6.07	1060.00	6.12		
0.6667	5.87	62.00	5.94	490.00	6.07	1070.00	6.12		
0.7500	5.87	64.00	5.94	500.00	6.07	1080.00	6.12		
0.8333	5.86	66.00	5.94	510.00	6.07	1090.00	6.12		
0.9167	5.86	68.00	5.94	520.00	6.08	1100.00	6.12		
1.00	5.87	70.00	5.94	530.00	6.08	1110.00	6.12		
1.08	5.86	72.00	5.95	540.00	6.08	1120.00	6.12		
1.17	5.86	74.00	5.94	550.00	6.08	1130.00	6.13		
1.25	5.86	76.00	5.94	560.00	6.08	1140.00	6.12		
1.33	5.86	78.00	5.94	570.00	6.08	1150.00	6.13		
1.42	5.87	80.00	5.95	580.00	6.08	1160.00	6.13		
1.50	5.87	82.00	5.96	590.00	6.08	1170.00	6.12		
1.58	5.87	84.00	5.96	600.00	6.08	1180.00	6.12		
1.67	5.87	86.00	5.95	610.00	6.09	1190.00	6.13		
1.75	5.87	88.00	5.96	620.00	6.09	1200.00	6.13		
1.83	5.87	90.00	5.96	630.00	6.09	1210.00	6.13		
1.92	5.87	92.00	5.95	640.00	6.08	1220.00	6.13		
2.00	5.87	94.00	5.96	650.00	6.09	1230.00	6.12		
2.50	5.87	96.00	5.96	660.00	6.09	1240.00	6.12		
3.00	5.86	98.00	5.96	670.00	6.09	1250.00	6.13		
3.50	5.86	100.00	5.97	680.00	6.09	1260.00	6.12		
4.00	5.86	110.00	5.97	690.00	6.09	1270.00	6.14		
4.50	5.86	120.00	5.98	700.00	6.09	1280.00	6.13		
5.00	5.86	130.00	5.99	710.00	6.09	1290.00	6.12		
5.50	5.86	140.00	5.98	720.00	6.09	1300.00	6.13		
6.00	5.86	150.00	5.99	730.00	6.09	1310.00	6.13		
6.50	5.87	160.00	6.00	740.00	6.09	1320.00	6.13		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hermit Data Loggers During 24 Hour Pump Test

OB - 5									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0.0000	7.35	6.50	7.36	150.00	7.48	720.00	7.55	1290.00	7.61
0.0033	7.31	7.00	7.37	160.00	7.49	730.00	7.55	1300.00	7.61
0.0066	7.30	7.50	7.36	170.00	7.49	740.00	7.55	1310.00	7.61
0.0099	7.30	8.00	7.37	180.00	7.50	750.00	7.55	1320.00	7.61
0.0133	7.30	8.50	7.37	190.00	7.51	760.00	7.55	1330.00	7.61
0.0166	7.30	9.00	7.37	200.00	7.51	770.00	7.55	1340.00	7.61
0.0200	7.30	9.50	7.37	210.00	7.51	780.00	7.56	1350.00	7.60
0.0233	7.30	10.00	7.37	220.00	7.52	790.00	7.56	1360.00	7.60
0.0266	7.30	12.00	7.38	230.00	7.52	800.00	7.56	1370.00	7.60
0.0300	7.30	14.00	7.39	240.00	7.52	810.00	7.55	1380.00	7.60
0.0333	7.30	16.00	7.39	250.00	7.52	820.00	7.56	1390.00	7.60
0.0500	7.35	18.00	7.38	260.00	7.52	830.00	7.56	1400.00	7.59
0.0666	7.35	20.00	7.39	270.00	7.52	840.00	7.56	1410.00	7.60
0.0833	7.35	22.00	7.40	280.00	7.52	850.00	7.56	1420.00	7.59
0.1000	7.35	24.00	7.40	290.00	7.51	860.00	7.56	1430.00	7.59
0.1166	7.35	26.00	7.39	300.00	7.52	870.00	7.56	1440.00	7.60
0.1333	7.35	28.00	7.40	310.00	7.53	880.00	7.56	1450.00	7.59
0.1500	7.35	30.00	7.41	320.00	7.52	890.00	7.56	1460.00	7.59
0.1666	7.35	32.00	7.41	330.00	7.52	900.00	7.56	1470.00	7.59
0.1833	7.35	34.00	7.41	340.00	7.52	910.00	7.56	1480.00	7.58
0.2000	7.35	36.00	7.42	350.00	7.52	920.00	7.56	1490.00	7.57
0.2166	7.35	38.00	7.43	360.00	7.51	930.00	7.56	1500.00	7.55
0.2333	7.35	40.00	7.42	370.00	7.52	940.00	7.56		
0.2500	7.35	42.00	7.42	380.00	7.52	950.00	7.56		
0.2666	7.35	44.00	7.42	390.00	7.52	960.00	7.56		
0.2833	7.35	46.00	7.43	400.00	7.52	970.00	7.56		
0.3000	7.35	48.00	7.43	410.00	7.52	980.00	7.56		
0.3166	7.35	50.00	7.44	420.00	7.52	990.00	7.57		
0.3333	7.35	52.00	7.44	430.00	7.52	1000.00	7.57		
0.4167	7.35	54.00	7.43	440.00	7.52	1010.00	7.57		
0.5000	7.35	56.00	7.43	450.00	7.52	1020.00	7.57		
0.5833	7.35	58.00	7.41	460.00	7.52	1030.00	7.57		
0.6667	7.35	60.00	7.42	470.00	7.52	1040.00	7.57		
0.7500	7.35	62.00	7.43	480.00	7.52	1050.00	7.57		
0.8333	7.35	64.00	7.44	490.00	7.53	1060.00	7.58		
0.9167	7.35	66.00	7.44	500.00	7.53	1070.00	7.58		
1.00	7.35	68.00	7.45	510.00	7.53	1080.00	7.58		
1.08	7.36	70.00	7.45	520.00	7.53	1090.00	7.58		
1.17	7.36	72.00	7.44	530.00	7.53	1100.00	7.59		
1.25	7.36	74.00	7.44	540.00	7.54	1110.00	7.58		
1.33	7.36	76.00	7.45	550.00	7.53	1120.00	7.59		
1.42	7.36	78.00	7.45	560.00	7.54	1130.00	7.59		
1.50	7.36	80.00	7.46	570.00	7.54	1140.00	7.60		
1.58	7.36	82.00	7.45	580.00	7.54	1150.00	7.60		
1.67	7.36	84.00	7.45	590.00	7.54	1160.00	7.60		
1.75	7.36	86.00	7.45	600.00	7.54	1170.00	7.59		
1.83	7.36	88.00	7.45	610.00	7.54	1180.00	7.60		
1.92	7.36	90.00	7.45	620.00	7.54	1190.00	7.60		
2.00	7.36	92.00	7.47	630.00	7.54	1200.00	7.60		
2.50	7.36	94.00	7.46	640.00	7.54	1210.00	7.61		
3.00	7.36	96.00	7.46	650.00	7.54	1220.00	7.61		
3.50	7.36	98.00	7.47	660.00	7.55	1230.00	7.60		
4.00	7.35	100.00	7.47	670.00	7.55	1240.00	7.60		
4.50	7.35	110.00	7.48	680.00	7.55	1250.00	7.60		
5.00	7.36	120.00	7.47	690.00	7.55	1260.00	7.60		
5.50	7.35	130.00	7.48	700.00	7.55	1270.00	7.61		
6.00	7.36	140.00	7.49	710.00	7.55	1280.00	7.60		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hermit Data Loggers During 24 Hour Pump Test

OB - 24									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0	4.43	6.50	4.48	150.00	4.68	720.00	4.78	1290.00	4.82
0.0033	4.44	7.00	4.49	160.00	4.69	730.00	4.78	1300.00	4.82
0.0066	4.44	7.50	4.49	170.00	4.69	740.00	4.78	1310.00	4.82
0.0099	4.43	8.00	4.49	180.00	4.69	750.00	4.78	1320.00	4.81
0.0133	4.43	8.50	4.50	190.00	4.70	760.00	4.78	1330.00	4.82
0.0166	4.43	9.00	4.50	200.00	4.70	770.00	4.79	1340.00	4.81
0.02	4.43	9.50	4.50	210.00	4.70	780.00	4.79	1350.00	4.81
0.0233	4.44	10.00	4.50	220.00	4.70	790.00	4.79	1360.00	4.80
0.0266	4.43	12.00	4.52	230.00	4.72	800.00	4.79	1370.00	4.80
0.03	4.43	14.00	4.54	240.00	4.72	810.00	4.79	1380.00	4.81
0.0333	4.43	16.00	4.54	250.00	4.72	820.00	4.79	1390.00	4.81
0.05	4.43	18.00	4.54	260.00	4.71	830.00	4.79	1400.00	4.79
0.0666	4.43	20.00	4.55	270.00	4.72	840.00	4.78	1410.00	4.79
0.0833	4.43	22.00	4.56	280.00	4.72	850.00	4.79	1420.00	4.80
0.1	4.43	24.00	4.57	290.00	4.72	860.00	4.79	1430.00	4.79
0.1166	4.43	26.00	4.56	300.00	4.73	870.00	4.79	1440.00	4.79
0.1333	4.43	28.00	4.58	310.00	4.73	880.00	4.79	1450.00	4.79
0.15	4.43	30.00	4.58	320.00	4.73	890.00	4.79	1460.00	4.78
0.1666	4.43	32.00	4.58	330.00	4.73	900.00	4.79	1470.00	4.79
0.1833	4.43	34.00	4.59	340.00	4.72	910.00	4.79	1480.00	4.78
0.2	4.43	36.00	4.60	350.00	4.73	920.00	4.79	1490.00	4.72
0.2166	4.43	38.00	4.60	360.00	4.73	930.00	4.79	1500.00	4.67
0.2333	4.43	40.00	4.60	370.00	4.73	940.00	4.79	1510.00	4.65
0.25	4.43	42.00	4.61	380.00	4.74	950.00	4.79		
0.2666	4.43	44.00	4.60	390.00	4.74	960.00	4.79		
0.2833	4.43	46.00	4.62	400.00	4.74	970.00	4.80		
0.3	4.43	48.00	4.61	410.00	4.75	980.00	4.80		
0.3166	4.43	50.00	4.62	420.00	4.75	990.00	4.80		
0.3333	4.43	52.00	4.62	430.00	4.75	1000.00	4.80		
0.4167	4.43	54.00	4.62	440.00	4.75	1010.00	4.81		
0.5	4.43	56.00	4.62	450.00	4.75	1020.00	4.80		
0.5833	4.43	58.00	4.62	460.00	4.76	1030.00	4.80		
0.6667	4.43	60.00	4.62	470.00	4.76	1040.00	4.80		
0.75	4.44	62.00	4.62	480.00	4.76	1050.00	4.81		
0.8333	4.44	64.00	4.62	490.00	4.76	1060.00	4.81		
0.9167	4.44	66.00	4.62	500.00	4.76	1070.00	4.81		
1.00	4.44	68.00	4.63	510.00	4.76	1080.00	4.81		
1.08	4.44	70.00	4.63	520.00	4.76	1090.00	4.81		
1.17	4.44	72.00	4.64	530.00	4.76	1100.00	4.82		
1.25	4.44	74.00	4.64	540.00	4.76	1110.00	4.82		
1.33	4.44	76.00	4.63	550.00	4.77	1120.00	4.82		
1.42	4.44	78.00	4.64	560.00	4.77	1130.00	4.82		
1.50	4.44	80.00	4.64	570.00	4.77	1140.00	4.82		
1.58	4.45	82.00	4.64	580.00	4.77	1150.00	4.82		
1.67	4.45	84.00	4.65	590.00	4.77	1160.00	4.82		
1.75	4.45	86.00	4.64	600.00	4.77	1170.00	4.82		
1.83	4.45	88.00	4.64	610.00	4.77	1180.00	4.82		
1.92	4.45	90.00	4.64	620.00	4.77	1190.00	4.82		
2.00	4.45	92.00	4.65	630.00	4.77	1200.00	4.81		
2.50	4.45	94.00	4.65	640.00	4.78	1210.00	4.81		
3.00	4.46	96.00	4.65	650.00	4.78	1220.00	4.82		
3.50	4.46	98.00	4.65	660.00	4.78	1230.00	4.82		
4.00	4.46	100.00	4.65	670.00	4.78	1240.00	4.82		
4.50	4.47	110.00	4.66	680.00	4.78	1250.00	4.81		
5.00	4.47	120.00	4.66	690.00	4.78	1260.00	4.82		
5.50	4.48	130.00	4.67	700.00	4.79	1270.00	4.82		
6.00	4.48	140.00	4.67	710.00	4.78	1280.00	4.81		
6.50	6.92	160.00	7.14	740.00	7.20	1320.00	7.24		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hermit Data Logger During 24 Hour Pump Test

PW - 1 (PUMPING)									
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0.0000	9.44	6.50	11.13	150.00	11.54	720.00	11.63	1290.00	11.65
0.0033	9.44	7.00	11.13	160.00	11.56	730.00	11.64	1300.00	11.67
0.0066	9.46	7.50	11.12	170.00	11.58	740.00	11.65	1310.00	11.64
0.0099	9.49	8.00	11.15	180.00	11.59	750.00	11.66	1320.00	11.65
0.0133	9.50	8.50	11.18	190.00	11.58	760.00	11.68	1330.00	11.64
0.0166	9.51	9.00	11.18	200.00	11.60	770.00	11.68	1340.00	11.64
0.0200	9.53	9.50	11.20	210.00	11.59	780.00	11.67	1350.00	11.63
0.0233	9.56	10.00	11.19	220.00	11.61	790.00	11.68	1360.00	11.64
0.0266	9.60	12.00	11.23	230.00	11.61	800.00	11.68	1370.00	11.65
0.0300	9.64	14.00	11.29	240.00	11.44	810.00	11.61	1380.00	11.66
0.0333	9.66	16.00	11.27	250.00	11.45	820.00	11.64	1390.00	11.63
0.0500	9.79	18.00	11.30	260.00	11.44	830.00	11.65	1400.00	11.63
0.0666	9.92	20.00	11.32	270.00	11.45	840.00	11.63	1410.00	11.63
0.0833	9.97	22.00	11.34	280.00	11.46	850.00	11.63	1420.00	11.62
0.1000	10.06	24.00	11.35	290.00	11.45	860.00	11.64	1430.00	11.59
0.1166	10.14	26.00	11.35	300.00	11.48	870.00	11.63	1440.00	11.62
0.1333	10.16	28.00	11.36	310.00	11.48	880.00	11.64	1450.00	11.60
0.1500	10.23	30.00	11.39	320.00	11.49	890.00	11.66	1460.00	11.60
0.1666	10.28	32.00	11.38	330.00	11.49	900.00	11.66	1470.00	11.60
0.1833	10.30	34.00	11.40	340.00	11.50	910.00	11.63	1480.00	11.59
0.2000	10.36	36.00	11.42	350.00	11.49	920.00	11.65		
0.2166	10.38	38.00	11.43	360.00	11.50	930.00	11.64		
0.2333	10.40	40.00	11.44	370.00	11.48	940.00	11.66		
0.2500	10.45	42.00	11.44	380.00	11.50	950.00	11.65		
0.2666	10.47	44.00	11.44	390.00	11.52	960.00	11.66		
0.2833	10.47	46.00	11.45	400.00	11.51	970.00	11.67		
0.3000	10.49	48.00	11.44	410.00	11.52	980.00	11.66		
0.3166	10.51	50.00	11.46	420.00	11.52	990.00	11.68		
0.3333	10.53	52.00	11.47	430.00	11.52	1000.00	11.64		
0.4167	10.60	54.00	11.46	440.00	11.53	1010.00	11.66		
0.5000	10.63	56.00	11.46	450.00	11.54	1020.00	11.66		
0.5833	10.69	58.00	11.45	460.00	11.54	1030.00	11.66		
0.6667	10.71	60.00	11.46	470.00	11.55	1040.00	11.66		
0.7500	10.74	62.00	11.47	480.00	11.55	1050.00	11.66		
0.8333	10.74	64.00	11.46	490.00	11.54	1060.00	11.67		
0.9167	10.77	66.00	11.49	500.00	11.54	1070.00	11.66		
1.00	10.79	68.00	11.47	510.00	11.55	1080.00	11.67		
1.08	10.82	70.00	11.48	520.00	11.59	1090.00	11.67		
1.17	10.81	72.00	11.48	530.00	11.56	1100.00	11.68		
1.25	10.81	74.00	11.50	540.00	11.59	1110.00	11.66		
1.33	10.85	76.00	11.49	550.00	11.59	1120.00	11.69		
1.42	10.85	78.00	11.50	560.00	11.59	1130.00	11.68		
1.50	10.87	80.00	11.50	570.00	11.56	1140.00	11.64		
1.58	10.89	82.00	11.50	580.00	11.59	1150.00	11.66		
1.67	10.88	84.00	11.51	590.00	11.59	1160.00	11.66		
1.75	10.89	86.00	11.49	600.00	11.60	1170.00	11.66		
1.83	10.90	88.00	11.50	610.00	11.61	1180.00	11.65		
1.92	10.91	90.00	11.48	620.00	11.61	1190.00	11.66		
2.00	10.91	92.00	11.51	630.00	11.64	1200.00	11.64		
2.50	10.96	94.00	11.53	640.00	11.61	1210.00	11.67		
3.00	10.98	96.00	11.51	650.00	11.63	1220.00	11.66		
3.50	11.00	98.00	11.50	660.00	11.64	1230.00	11.66		
4.00	11.02	100.00	11.50	670.00	11.63	1240.00	11.65		
4.50	11.04	110.00	11.51	680.00	11.64	1250.00	11.65		
5.00	11.06	120.00	11.50	690.00	11.65	1260.00	11.63		
5.50	11.08	130.00	11.52	700.00	11.66	1270.00	11.65		
6.00	11.05	140.00	11.57	710.00	11.65	1280.00	11.63		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hermit Data Loggers During 24 Hour Pump Test

PW - 1 RECOVERY					
ELAPSED TIME (minutes)	DTW.	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0.0000	10.50	1.42	8.56	46.00	8.07
0.0033	10.40	1.50	8.55	48.00	8.05
0.0066	10.35	1.58	8.54	50.00	8.05
0.0099	10.31	1.67	8.53	52.00	8.06
0.0133	10.26	1.75	8.53	54.00	8.05
0.0166	10.22	1.83	8.52	56.00	8.04
0.0200	10.18	1.92	8.51	58.00	8.04
0.0233	10.14	2.00	8.51	60.00	8.04
0.0266	10.10	2.50	8.47	62.00	8.03
0.0300	10.07	3.00	8.45	64.00	8.02
0.0333	10.03	3.50	8.42	66.00	8.03
0.0500	9.92	4.00	8.41	68.00	8.02
0.0666	9.77	4.50	8.40	70.00	8.01
0.0833	9.65	5.00	8.38	72.00	8.01
0.1000	9.53	5.50	8.36	74.00	8.00
0.1166	9.44	6.00	8.35	76.00	8.01
0.1333	9.36	6.50	8.34	78.00	8.01
0.1500	9.29	7.00	8.32	80.00	8.00
0.1666	9.23	7.50	8.31	82.00	8.00
0.1833	9.17	8.00	8.30	84.00	8.00
0.2000	9.13	8.50	8.29	86.00	7.99
0.2166	9.09	9.00	8.29	88.00	8.00
0.2333	9.05	9.50	8.27	90.00	7.99
0.2500	9.02	10.00	8.27		
0.2666	8.99	12.00	8.25		
0.2833	8.96	14.00	8.22		
0.3000	8.93	16.00	8.21		
0.3166	8.91	18.00	8.19		
0.3333	8.89	20.00	8.17		
0.4167	8.81	22.00	8.17		
0.5000	8.76	24.00	8.15		
0.5833	8.73	26.00	8.14		
0.6667	8.69	28.00	8.13		
0.7500	8.67	30.00	8.14		
0.8333	8.65	32.00	8.12		
0.9167	8.63	34.00	8.11		
1.00	8.62	36.00	8.09		
1.08	8.60	38.00	8.10		
1.17	8.58	40.00	8.09		
1.25	8.57	42.00	8.08		
1.33	8.57	44.00	8.08		

* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hand Measurements During 24 Hour Pump Test

MW-4		MW-5		OB - 1		OB-2		OB-4		OB-6	
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0	9.03	0	10.15	0	8.54	0	5.05	0	6.42	0	6.67
60	9.03	60	10.43	89	8.57	60	5.16	60	6.5	60	7.04
120	9.03	120	10.5	198	8.57	120	5.18	120	6.52	120	7.08
180	9.04	180	10.46	264	8.55	180	5.22	180	6.52	180	7.1
240	9.05	240	10.47	335	8.55	240	5.23	240	6.54	240	7.12
300	9.06	300	10.47	375	8.57	300	5.25	300	6.53	300	7.12
360	9.05	360	10.49	510	8.6	360	5.25	360	6.56	360	7.13
480	9.07	420	10.49	584	8.62	420	5.26	420	6.57	420	7.16
540	9.1	480	10.51	641	8.59	480	5.27	480	6.68	480	7.2
600	9.11	540	10.53	717	8.6	540	5.38	540	6.7	540	7.2
660	9.09	600	10.57	778	8.6	600	5.27	600	6.66	600	7.3
720	9.08	660	10.54	880	8.6	660	5.26	660	6.58	660	7.18
780	9.08	720	10.54	941	8.6	720	5.28	720	6.66	720	7.11
840	9.09	780	10.55	957	8.61	780	5.27	780	6.6	780	7.2
900	9.09	840	10.56	1017	8.62	840	5.27	840	6.61	840	7.2
960	9.09	900	10.58	1025	8.62	900	5.29	900	6.61	900	7.2
1020	9.1	960	10.57	1145	8.63	960	5.3	960	6.62	960	7.21
1140	9.12	1140	10.57	1205	8.63	1140	5.3	1140	6.64	1140	7.22
1200	9.14	1200	10.59	1261	8.63	1200	5.33	1200	6.65	1200	7.25
1260	9.13	1260	10.58	1321	8.64	1260	5.33	1260	6.67	1260	7.24
1320	9.13	1320	10.59	1402	8.62	1320	5.32	1320	6.65	1320	7.24
1380	9.11	1380	10.59	1442	8.59	1380	5.32	1380	6.64	1380	7.23
1440	9.11	1440	10.57			1440	5.31	1440	6.63	1440	7.22

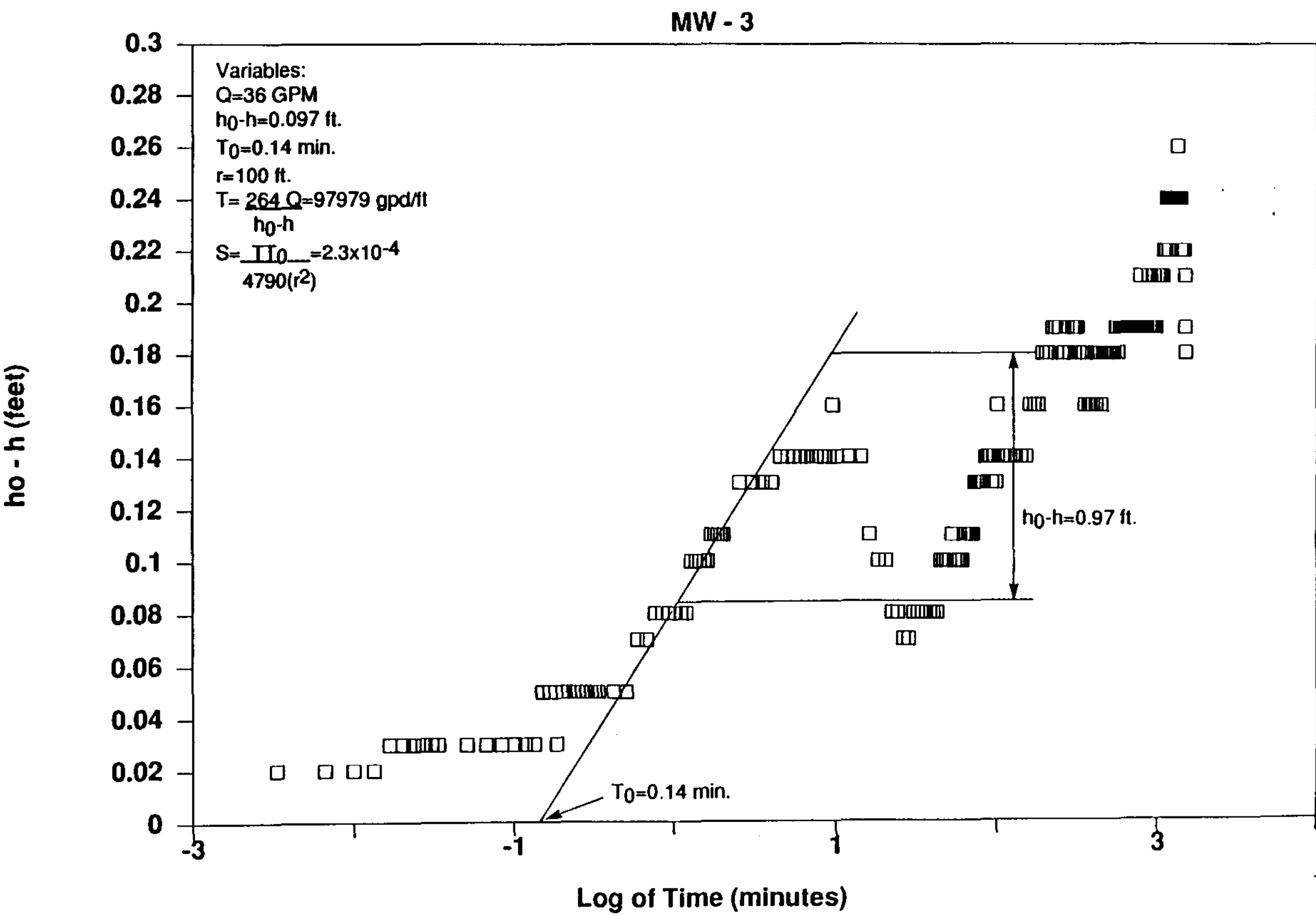
* All depth to water (DTW) values given as depth below top of casing in feet.

Water Levels Obtained From Hand Measurements During 24 Hour Pump Test

OB-7		OB-8		OB-9		OB-10		OB-11		OB-12	
ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW	ELAPSED TIME (minutes)	DTW
0	5.58	0	4.52	0	5.9	0	6.34	0	8.13	0	8.76
60	6.02	60	5.2	60	6.33	60	6.45	60	8.15	60	8.76
120	6.07	120	5.22	120	6.38	120	6.48	120	8.14	120	8.75
180	6.1	180	5.24	180	6.4	180	6.51	180	8.16	180	8.75
240	6.11	240	5.24	240	6.41	240	6.5	240	8.17	240	8.75
300	6.12	300	5.27	300	6.43	300	6.52	300	8.18	300	8.75
360	6.13	360	5.27	360	6.44	360	6.54	360	8.19	360	8.76
420	6.16	420	5.31	420	6.46	420	6.52	420	8.2	420	8.77
480	6.18	480	5.31	480	6.46	480	6.55	480	8.2	480	8.77
540	6.18	540	5.32	540	6.46	540	6.55	540	8.2	540	8.78
600	6.19	600	5.33	600	6.52	600	6.77	600	8.22	600	8.78
660	6.18	660	5.33	660	6.47	660	6.56	660	8.22	660	8.75
720	6.21	720	5.34	720	6.48	720	6.57	720	8.2	720	8.78
780	6.21	780	5.35	780	6.49	780	6.58	780	8.21	780	8.78
840	6.2	840	5.35	840	6.5	840	6.58	840	8.21	840	8.79
900	6.21	900	5.35	900	6.5	900	6.58	900	8.22	900	8.79
960	6.21	960	5.35	960	6.52	960	6.6	960	8.22	960	8.79
1140	6.23	1140	5.36	1140	6.53	1140	6.59	1140	8.23	1140	8.8
1200	6.24	1200	5.38	1200	6.53	1200	6.62	1200	8.24	1200	8.82
1260	6.24	1260	5.37	1260	6.52	1260	6.61	1260	8.23	1260	8.82
1320	6.23	1320	5.36	1320	6.52	1320	6.61	1320	8.23	1320	8.81
1380	6.22	1380	5.37	1380	6.51	1380	6.61	1380	8.23	1380	8.79
1440	6.22	1440	5.34	1440	6.51	1440	6.6	1440	8.22	1440	8.78

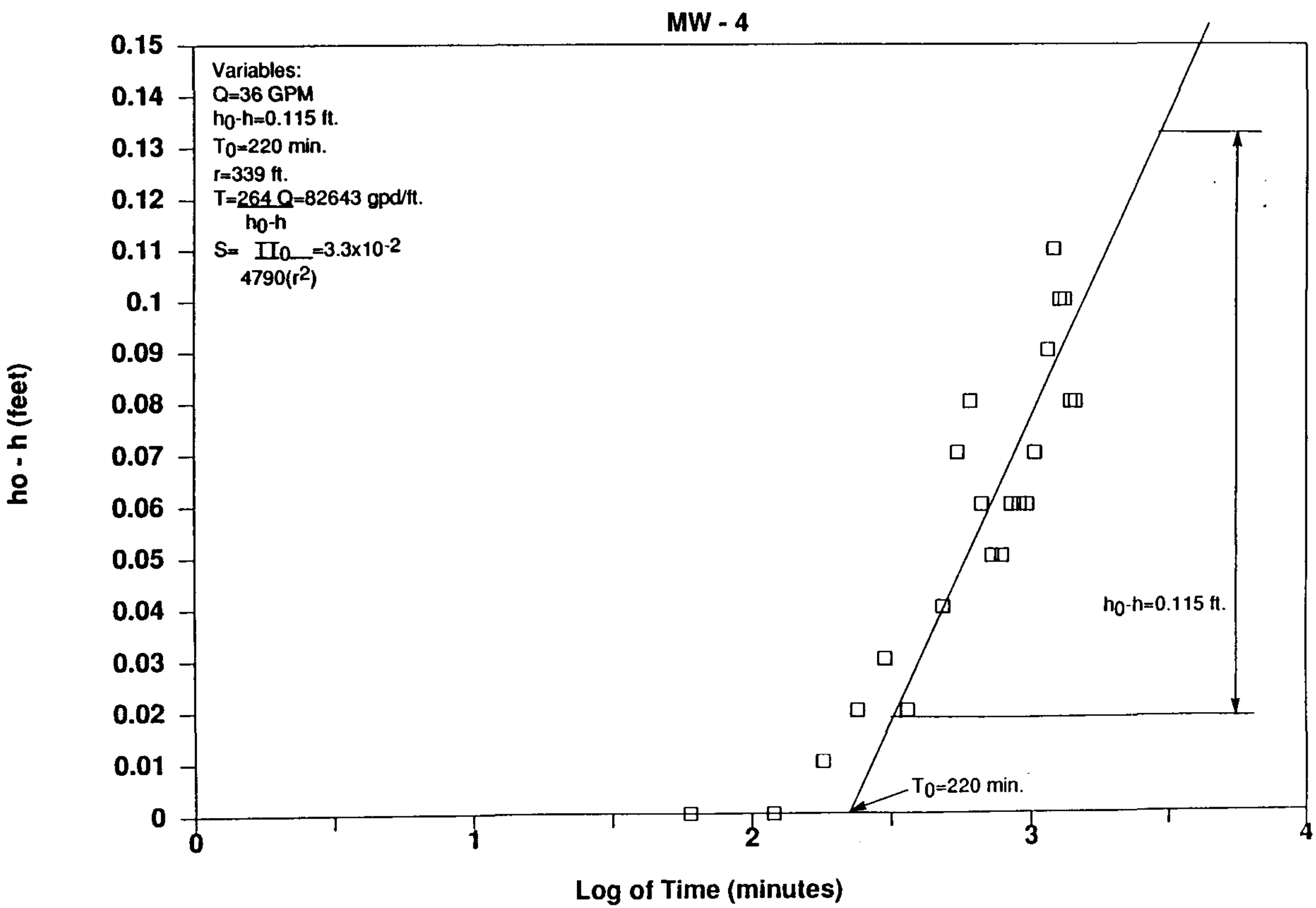
* All depth to water (DTW) values given as depth below top of casing in feet.

Jacob Plot

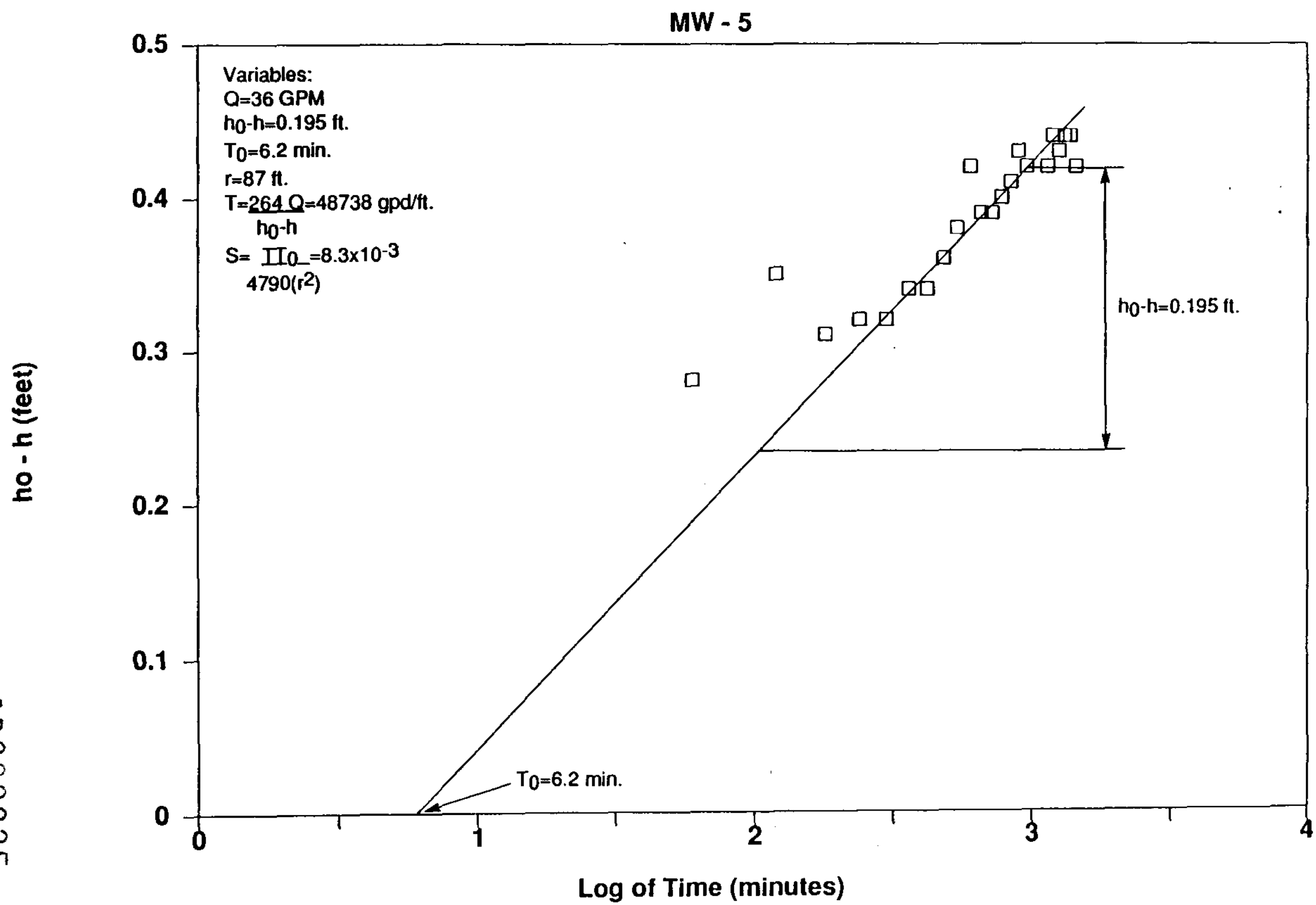


AR300823

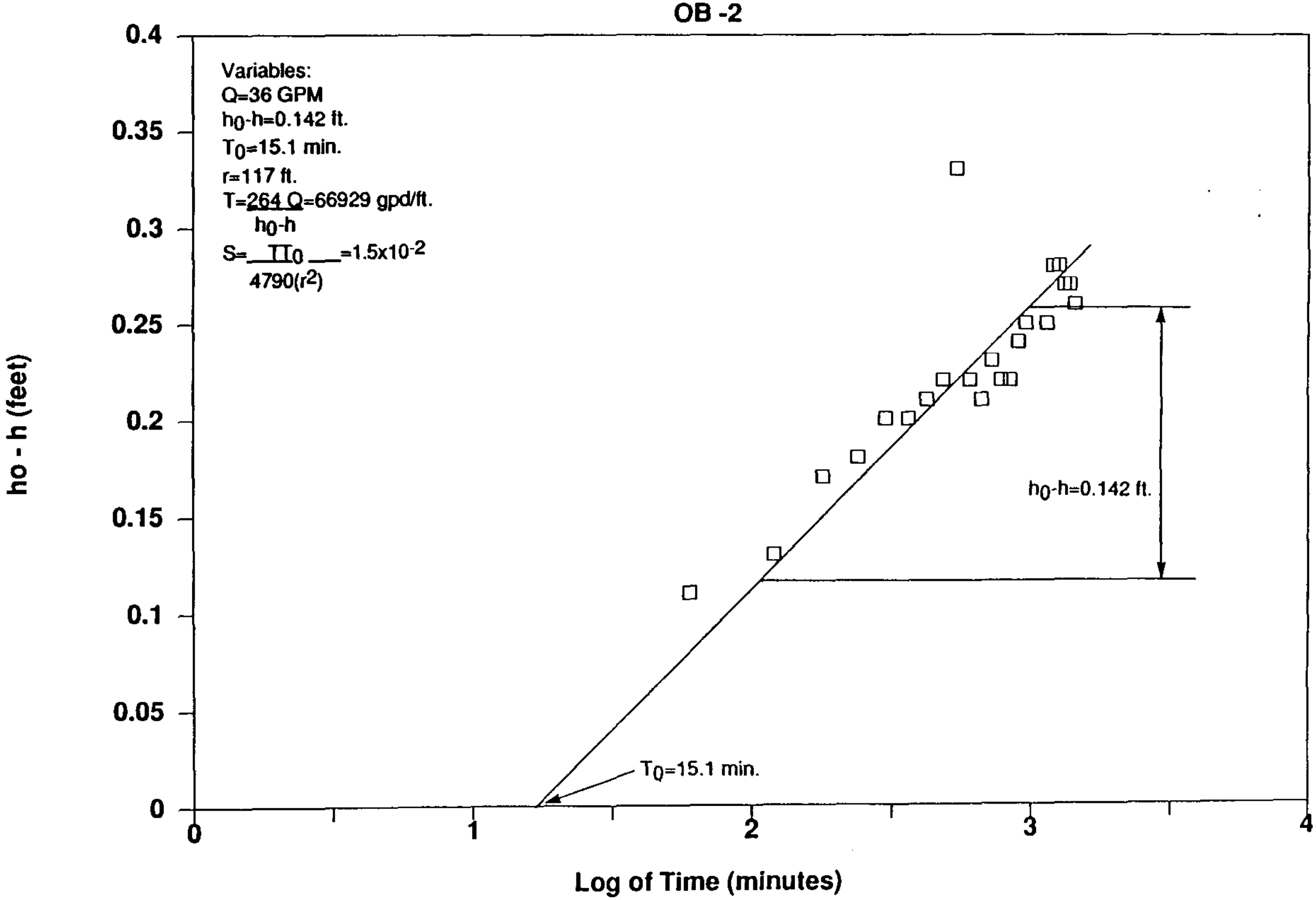
Jacob Plot


MW - 4
Variables:
Q=36 GPM
h0-h=0.115 ft.
T0=220 min.
r=339 ft.
T=264 Q=82643 gpd/ft.
h0-h
S= TT0 =3.3x10-2
4790(r2)
h0-h=0.115 ft.
T0=220 min.
ho - h (feet)
Log of Time (minutes)
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1
2
3
4

Jacob Plot

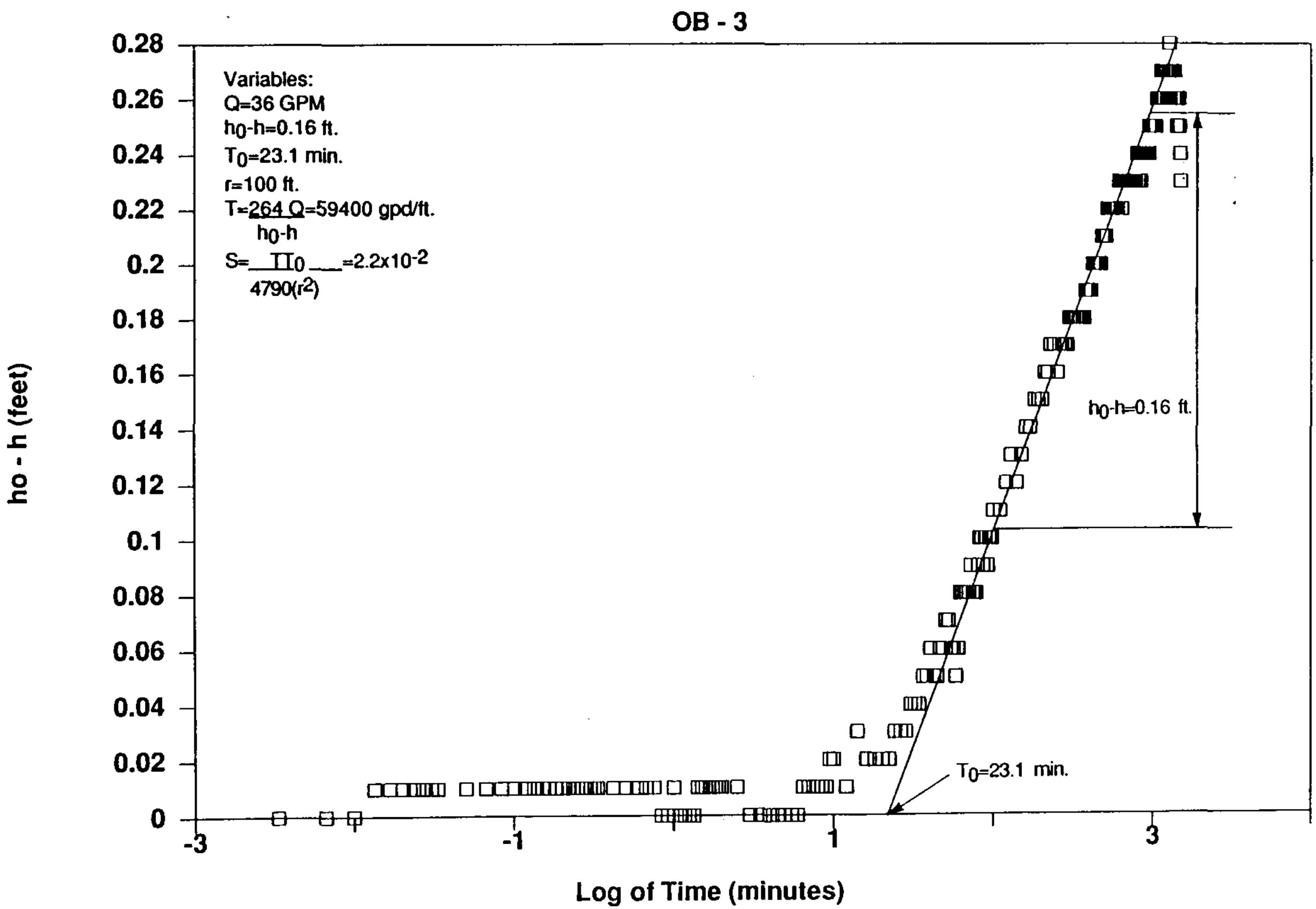

MW - 5
Variables:
Q=36 GPM
h0-h=0.195 ft.
T0=6.2 min.
r=87 ft.
T=264 Q=48738 gpd/ft.
h0-h
S= TT0 =8.3x10-3
4790(r2)
h0-h=0.195 ft.
T0=6.2 min.
ho - h (feet)
Log of Time (minutes)
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4

Jacob Plot



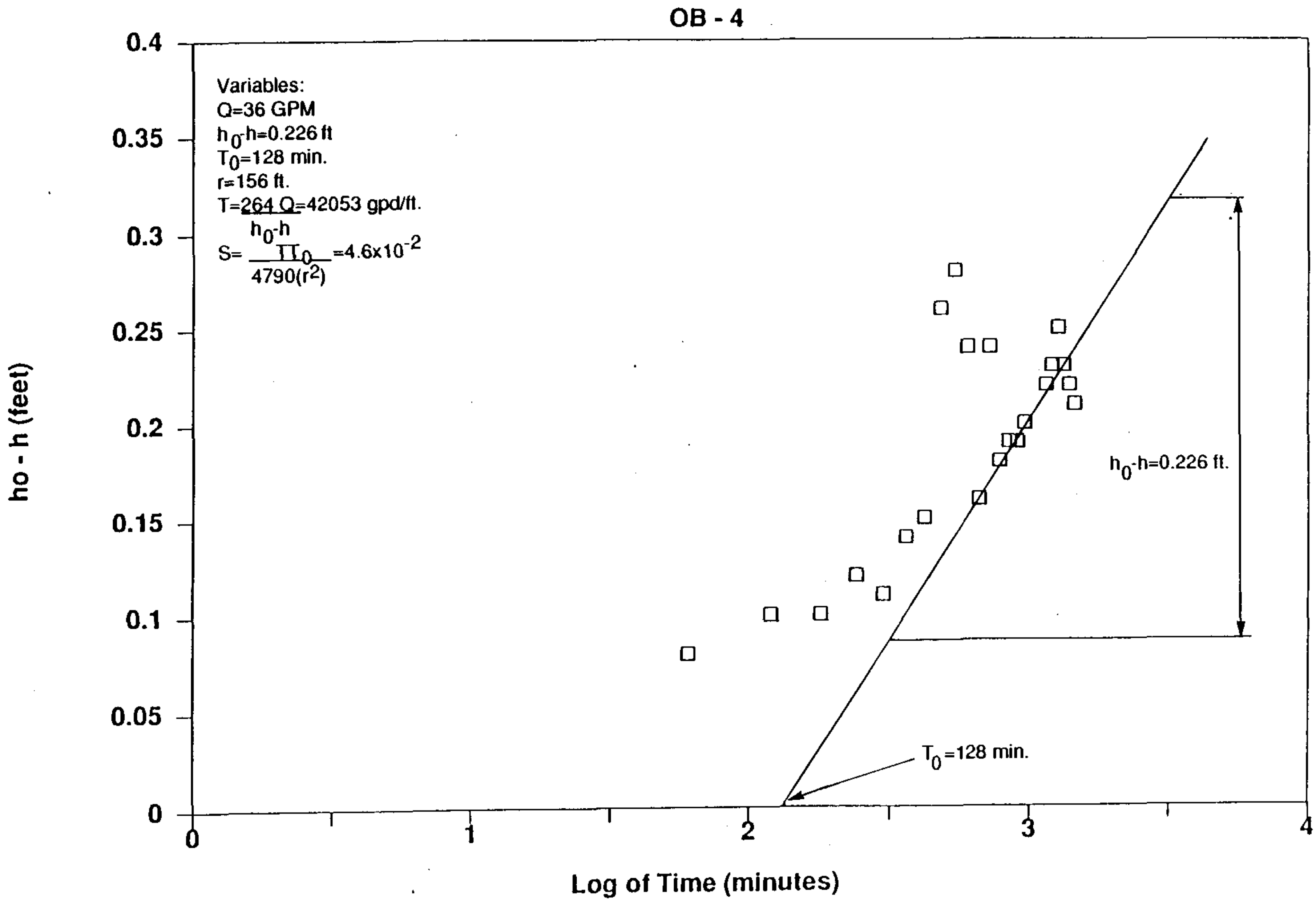
OB -2
Variables:
Q=36 GPM
h_0-h=0.142 ft.
T_0=15.1 min.
r=117 ft.
T=264 Q=66929 gpd/ft.
h_0-h
S=___TT_0___=1.5x10^{-2}
4790(r^2)
h_0-h=0.142 ft.
T_0=15.1 min.
ho - h (feet)
Log of Time (minutes)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4

Jacob Plot



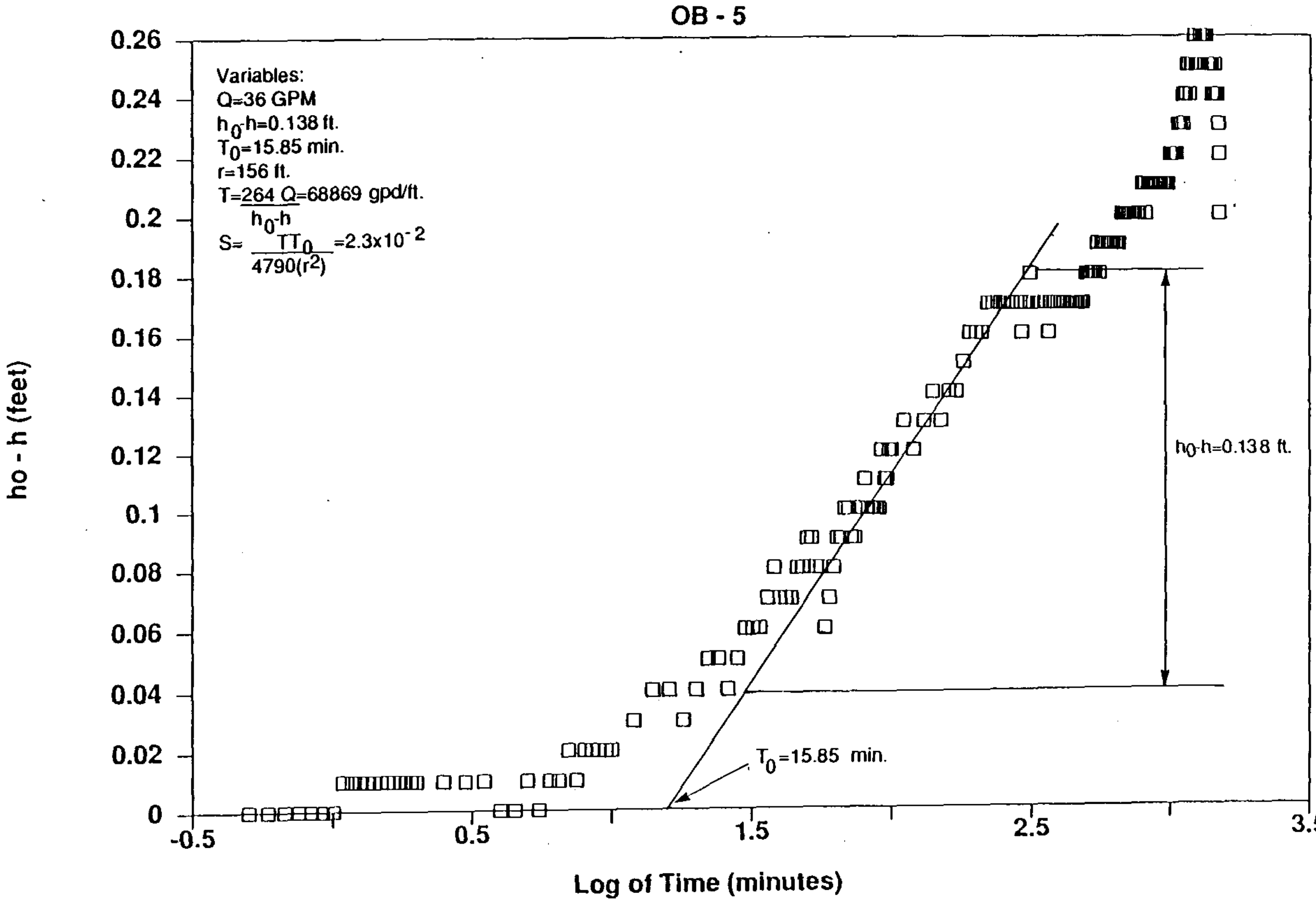
OB - 3
Variables:
Q=36 GPM
h_0-h=0.16 ft.
T_0=23.1 min.
r=100 ft.
T=264 Q=59400 gpd/ft.
h_0-h
S= TT0 =2.2x10^{-2}
4790(r^2)
h_0-h=0.16 ft.
T_0=23.1 min.
0.28
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-3
-1
1
3
ho - h (feet)
Log of Time (minutes)

Jacob Plot

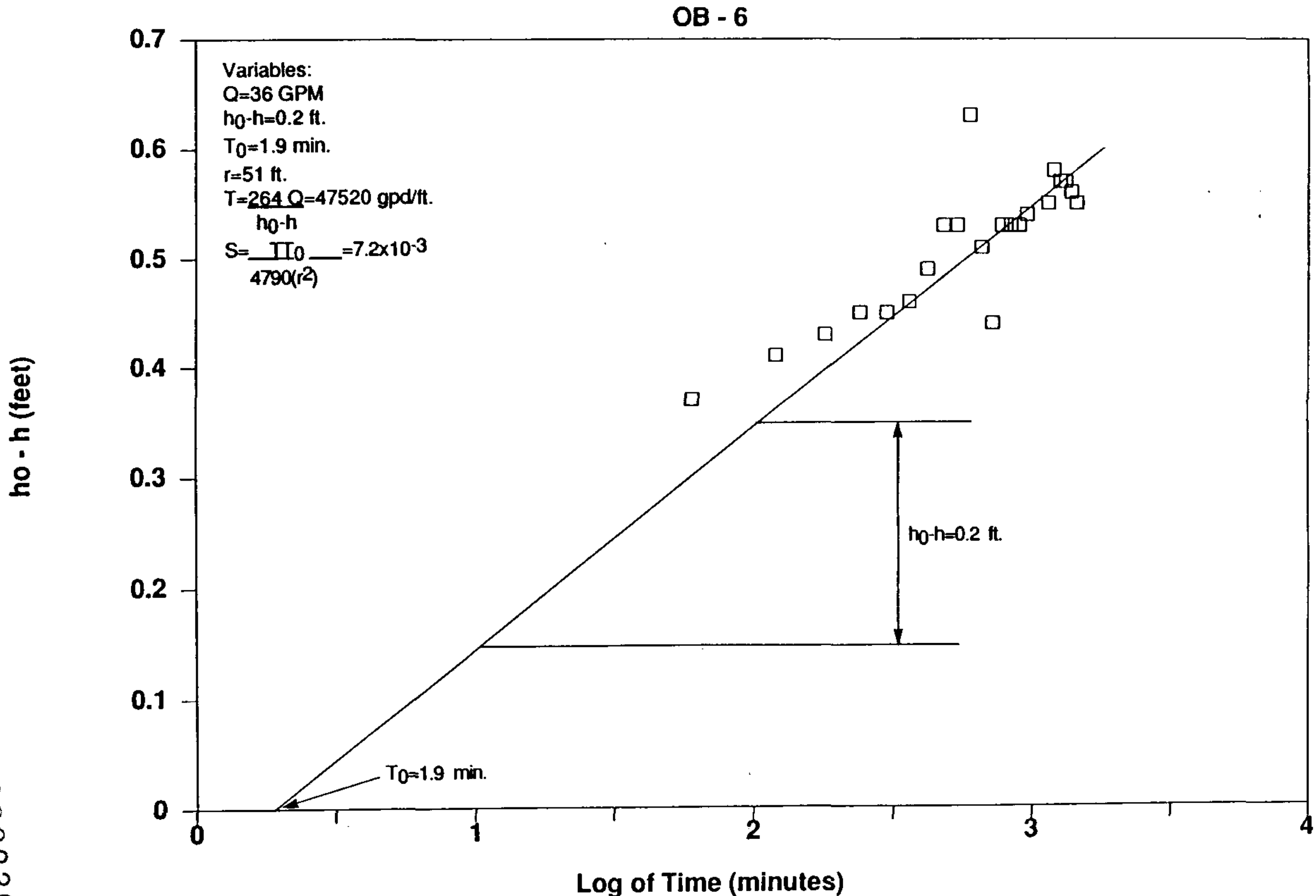


OB - 4
Variables:
Q=36 GPM
h_0-h=0.226 ft
T_0=128 min.
r=156 ft.
T=264 Q/h_0-h=42053 gpd/ft.
S= $T T_0$/4790(r^2)=4.6x10^{-2}
h_0-h=0.226 ft.
T_0=128 min.
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
ho - h (feet)
Log of Time (minutes)

Jacob Plot

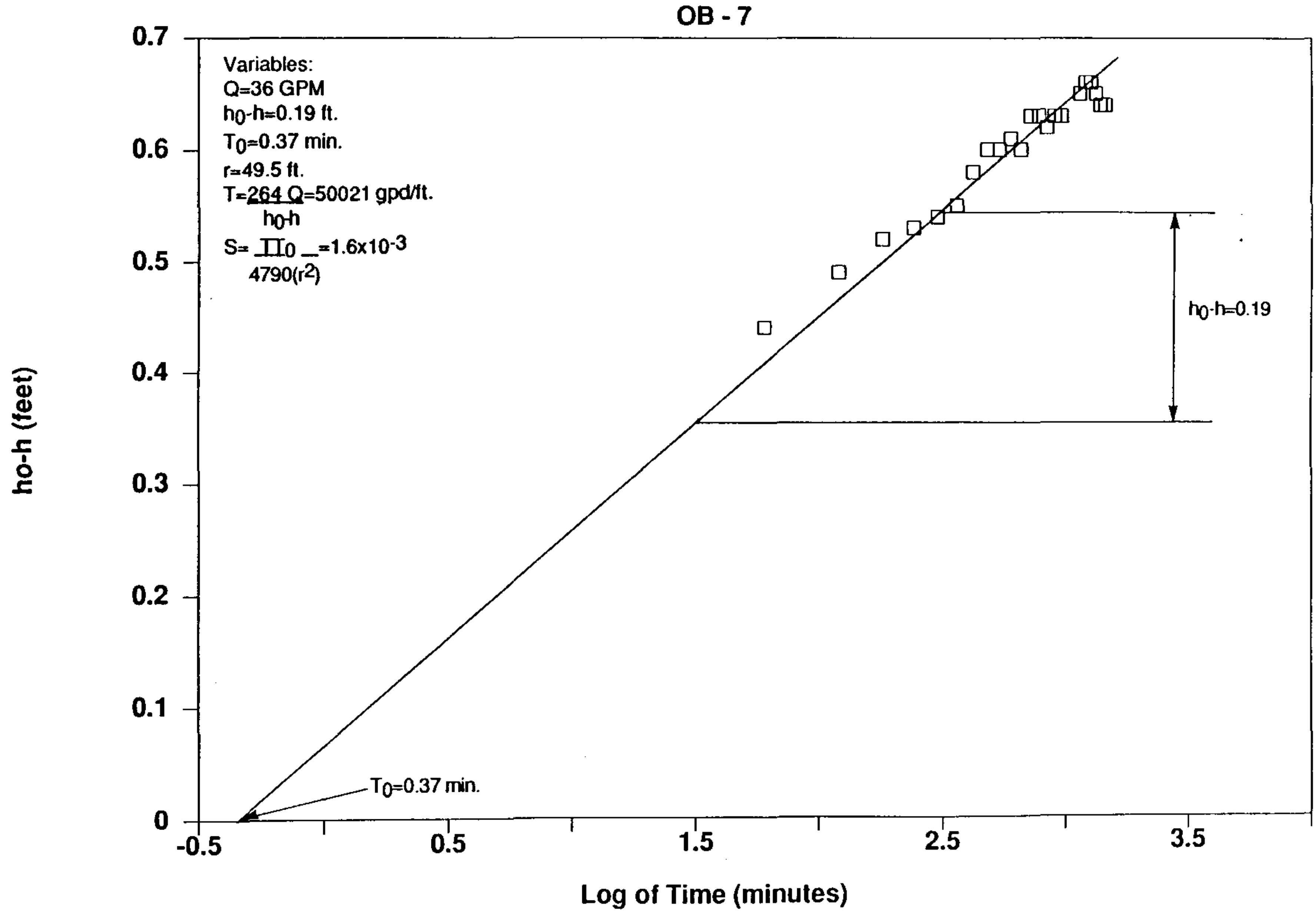

OB - 5
Variables:
Q=36 GPM
h_0-h=0.138 ft.
T_0=15.85 min.
r=156 ft.
T=264 Q/h_0-h=68869 gpd/ft.
S= $\frac{TT_0}{4790(r^2)}$=2.3x10^{-2}
h_0-h=0.138 ft.
T_0=15.85 min.
ho - h (feet)
Log of Time (minutes)
0.26
0.24
0.22
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
-0.5
0.5
1.5
2.5
3.5

Jacob Plot

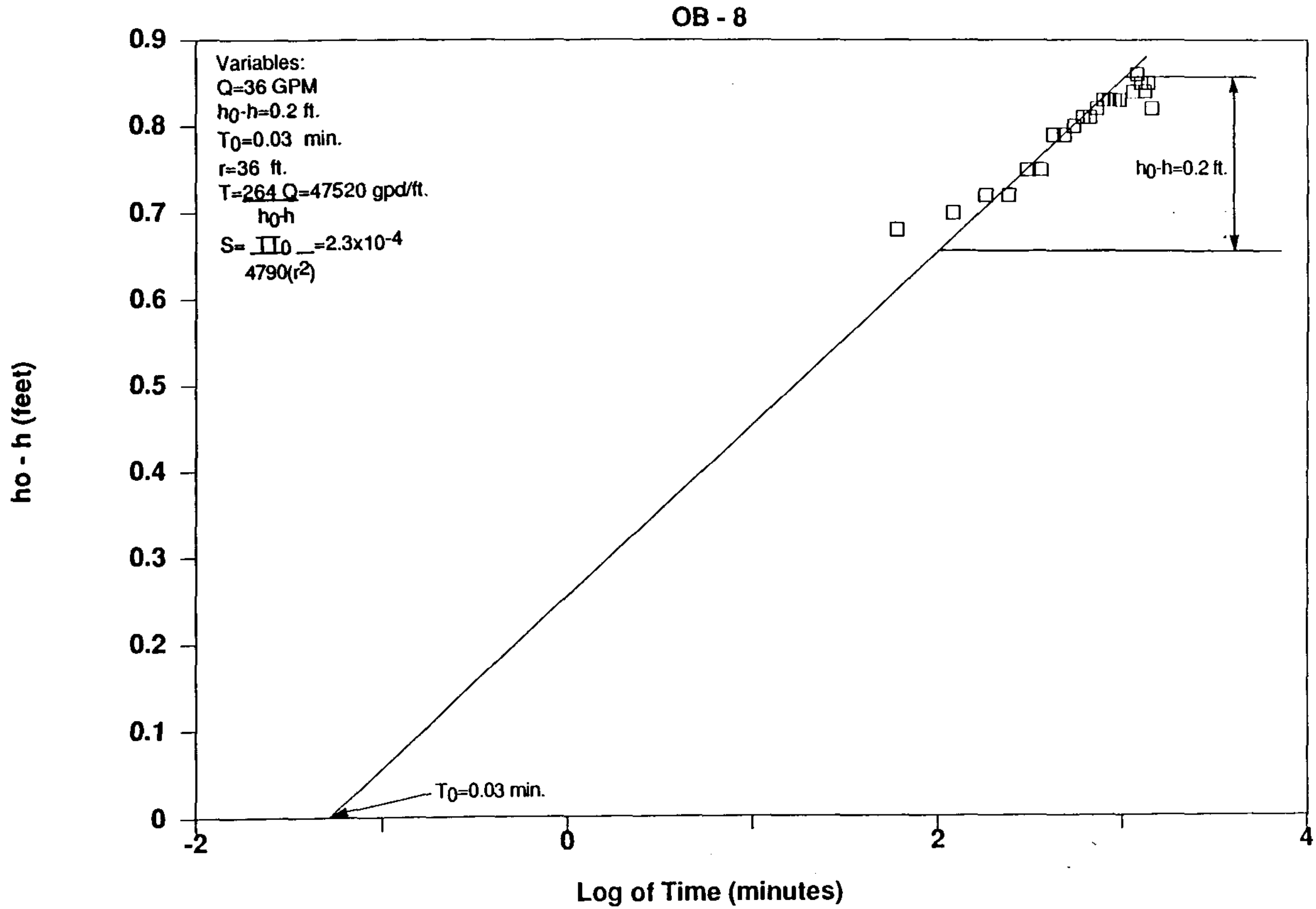


AR300830

Jacob Plot

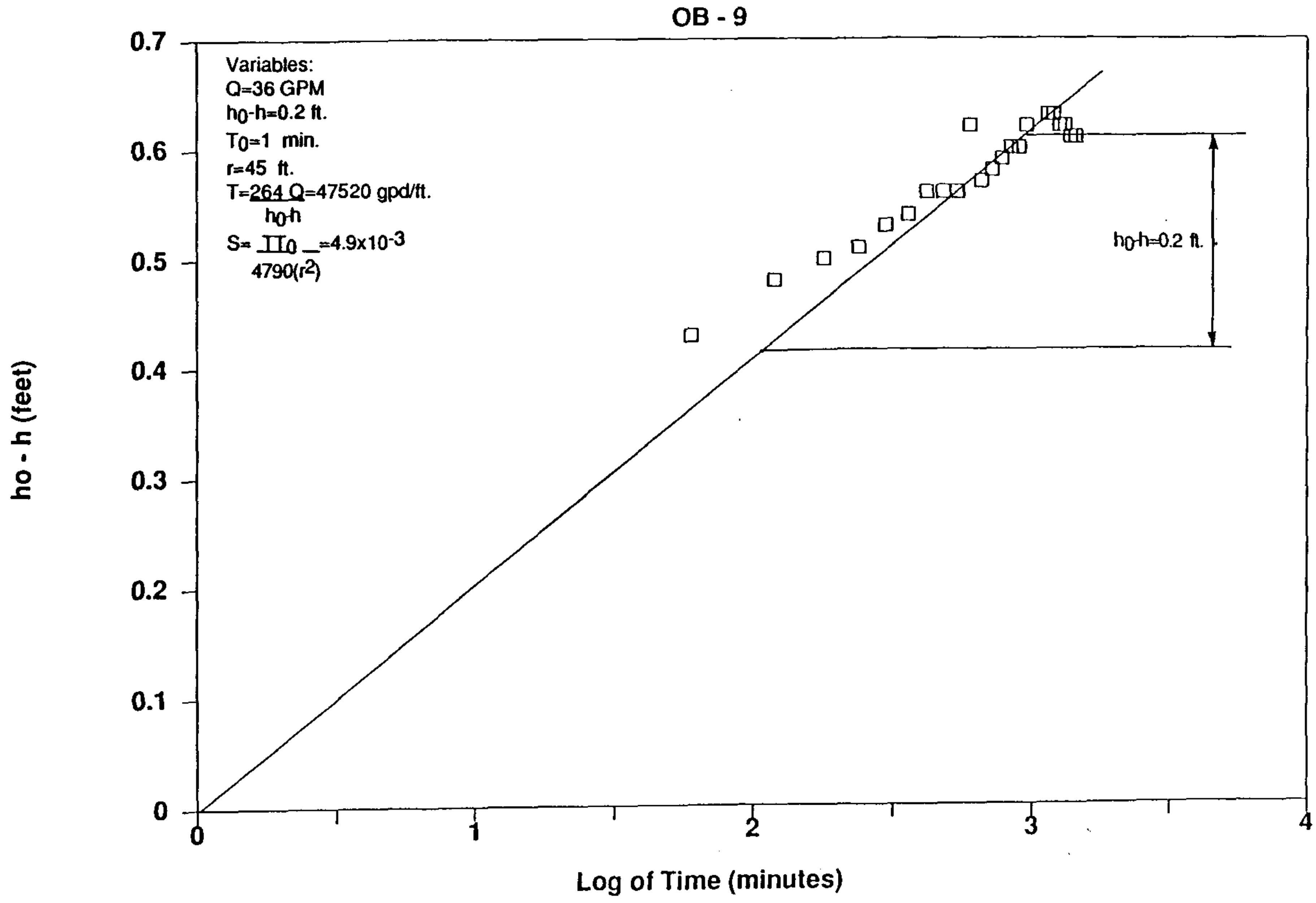

OB - 7
Variables:
Q=36 GPM
h0-h=0.19 ft.
T0=0.37 min.
r=49.5 ft.
T=264 Q=50021 gpd/ft.
h0-h
S= TT0 =1.6x10-3
4790(r2)
h0-h=0.19
T0=0.37 min.
ho-h (feet)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.5
0.5
1.5
2.5
3.5
Log of Time (minutes)

Jacob Plot

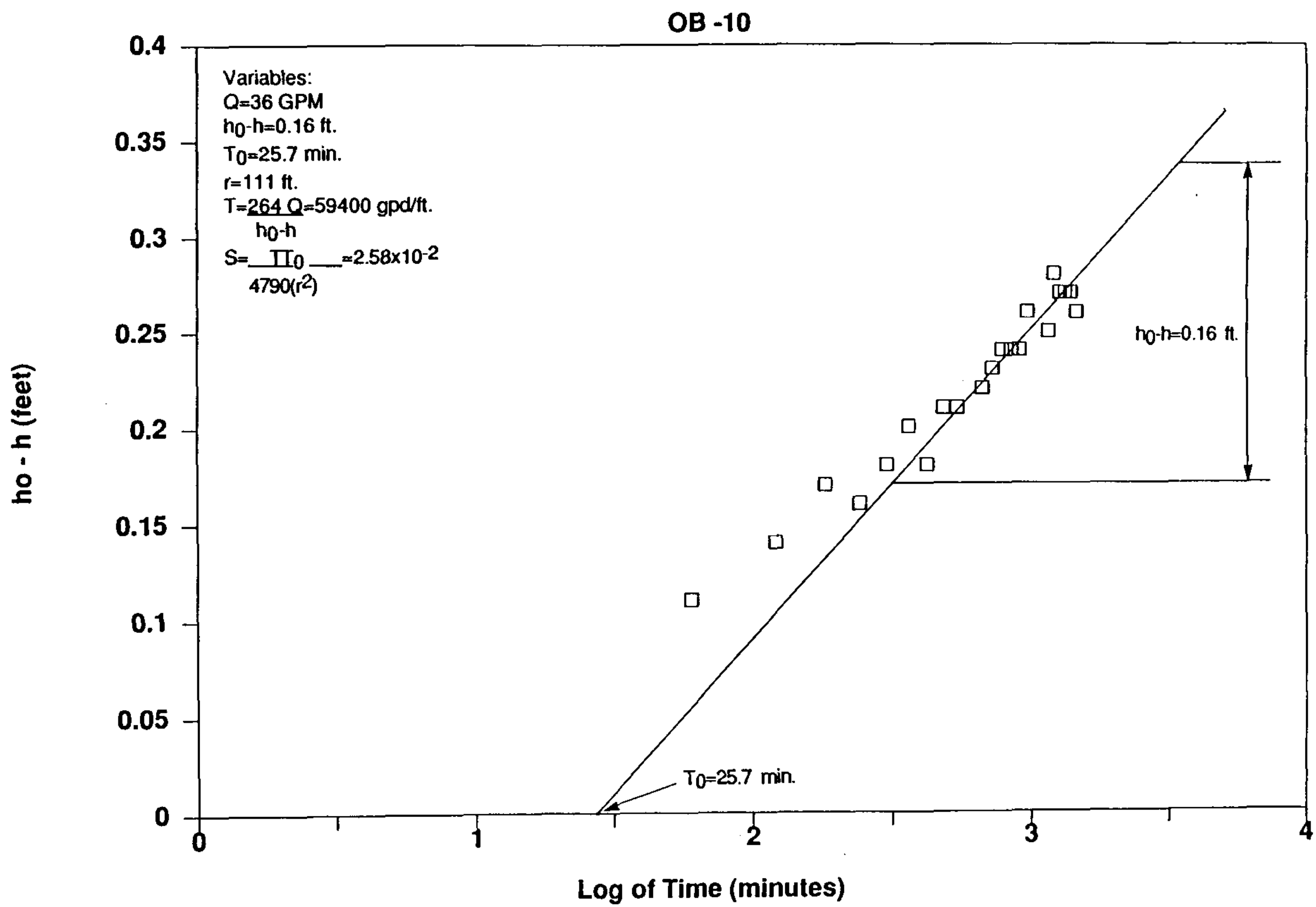


AR300832

Jacob Plot

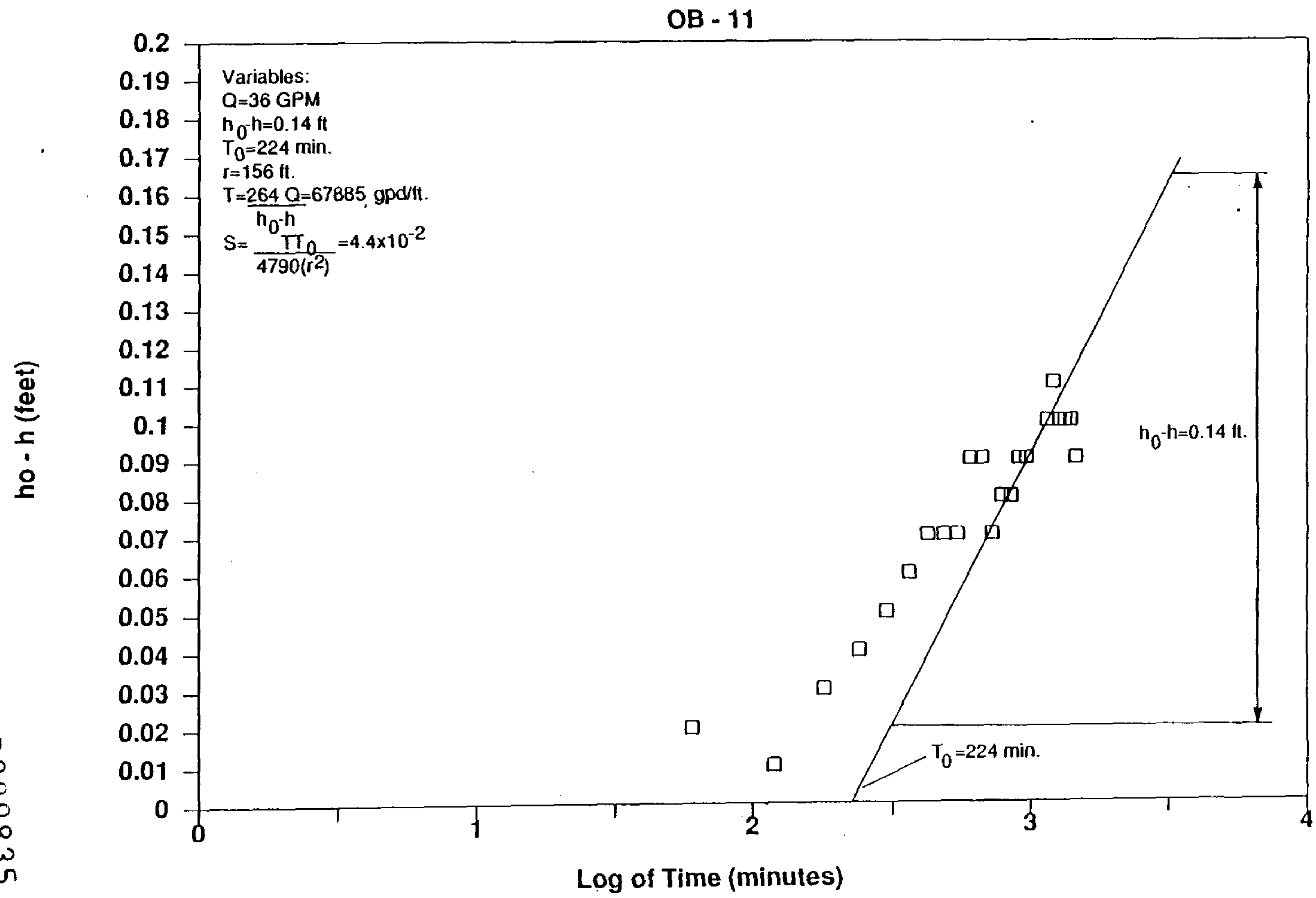

OB - 9
Variables:
Q=36 GPM
h_0-h=0.2 ft.
T_0=1 min.
r=45 ft.
T=264 Q=47520 gpd/ft.
h_0-h
S= TT_0 =4.9x10^{-3}
4790(r^2)
h_0-h=0.2 ft.
ho - h (feet)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
4
Log of Time (minutes)

Jacob Plot



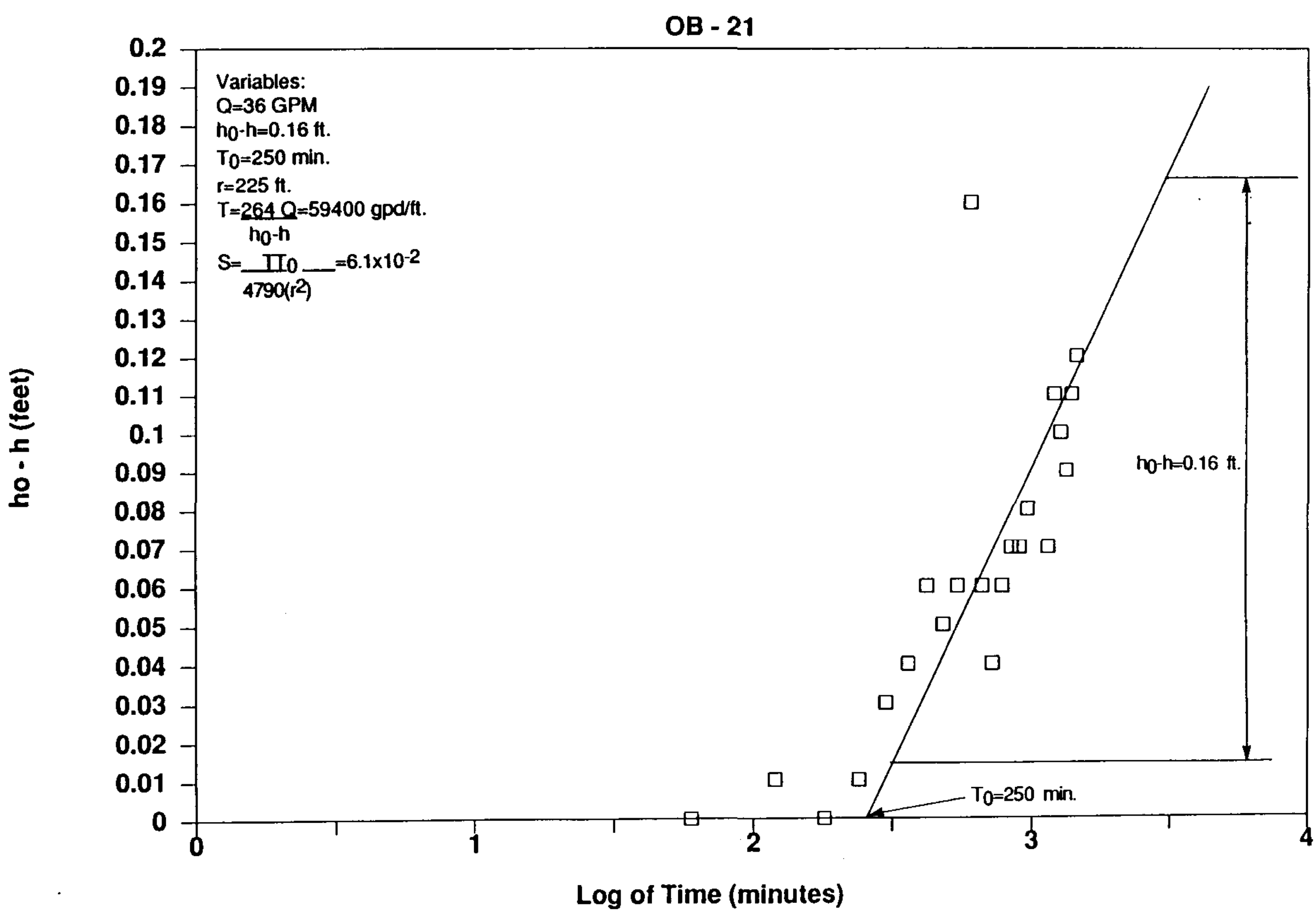
AR300834

Jacob Plot



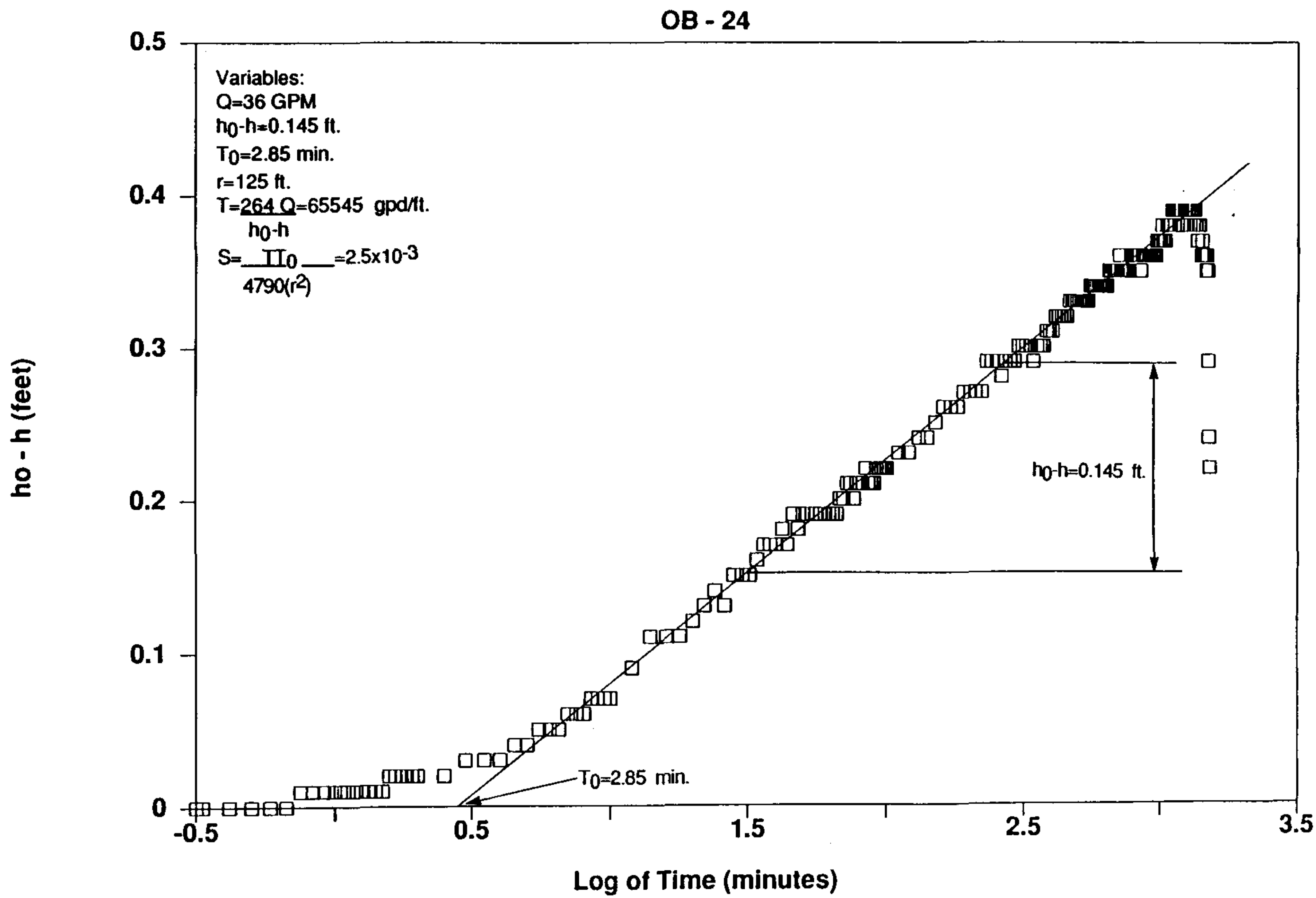
AR300835

Jacob Plot



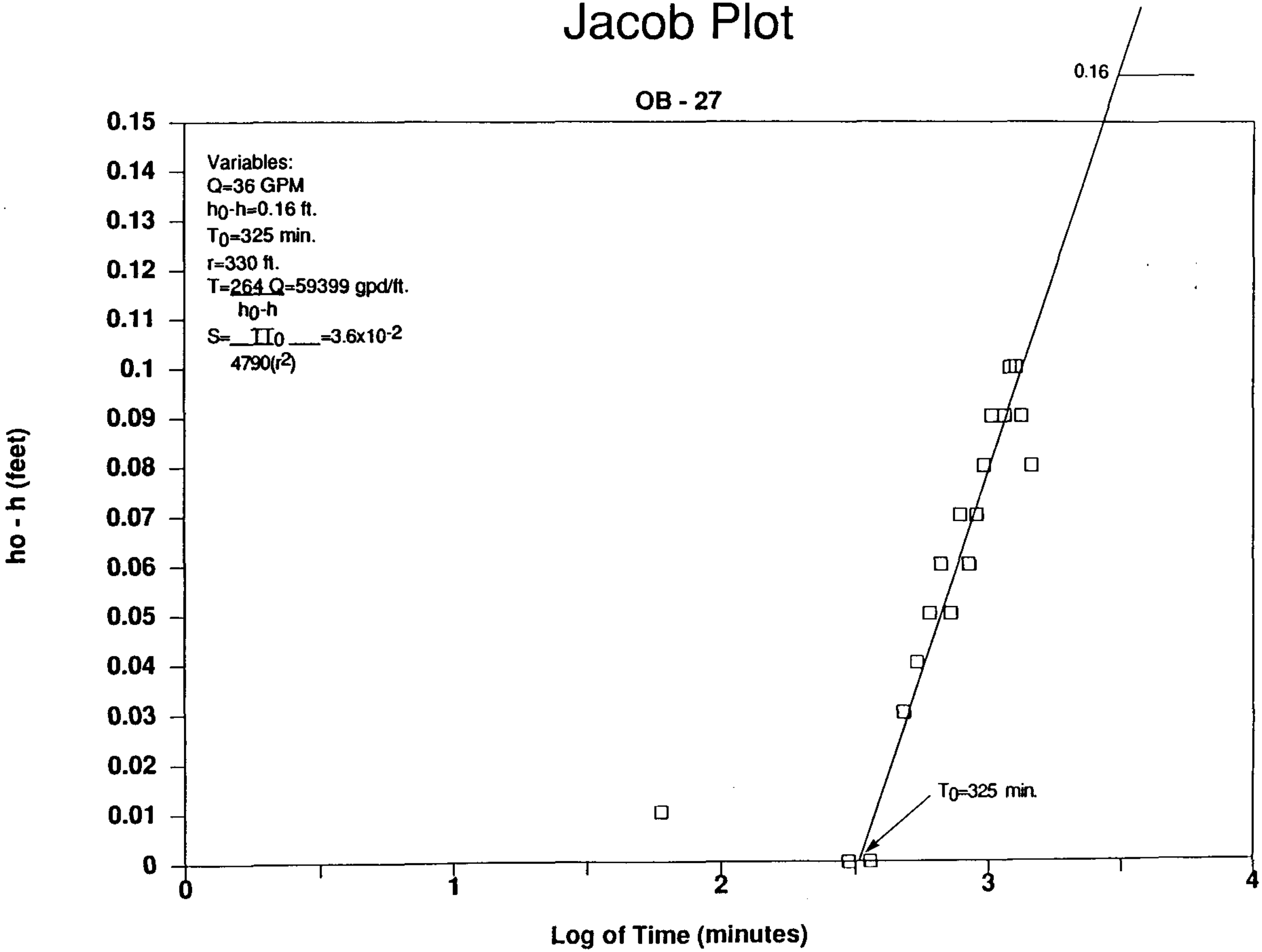
AR300836

Jacob Plot



AR300837

Jacob Plot



OB - 27
Variables:
Q=36 GPM
h0-h=0.16 ft.
T0=325 min.
r=330 ft.
T=264 Q=59399 gpd/ft.
h0-h
S=TT0=3.6x10-2
4790(r2)
0.16
T0=325 min.
ho - h (feet)
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
1
2
3
4
Log of Time (minutes)

APPENDIX F

DATA COLLECTED DURING THE TIDAL FLUCTUATION STUDY 11-12 FEBRUARY 1988

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-1

Date	Time	DTW
2/11/88		
Start	9:41	8.92
	11:39	8.89
	13:41	8.88
	15:44	8.86
	17:35	8.88
	19:37	8.90
	21:37	8.87
	23:39	8.85
2/12/88		
	1:34	8.80
	3:34	8.82
	5:34	8.07
	7:34	8.68
	9:33	8.66
Finish	11:34	8.63

Well OB-2

Date	Time	DTW
2/11/88		
Start	9:50	5.43
	11:50	5.42
	13:50	5.38
	15:54	5.39
	17:44	5.39
	19:48	5.40
	21:50	5.35
	23:48	5.34
2/12/88		
	1:44	5.27
	3:44	4.82*
	5:44	5.04
	7:43	5.05
	9:42	5.05
Finish	11:47	5.05

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-3

Date		Time	DTW
2/11/88			
	Start	9:51	6.23
		11:51	6.23
		13:51	6.19
		15:55	6.19
		17:45	6.19
		19:49	6.20
		21:52	6.16
		23:49	6.19
2/12/88			
		1:45	6.08
		3:45	5.65*
		5:44	5.92
		7:45	5.94
		9:43	5.94
	Finish	11:49	5.93

Well OB-4

Date		Time	DTW
2/11/88			
	Start	9:52	6.81
		11:53	6.79
		13:53	6.72
		15:56	6.76
		17:46	6.77
		19:50	6.78
		21:53	6.74
		23:50	6.74
2/12/88			
		1:46	6.68
		3:47	6.56
		5:45	6.50
		7:46	6.50
		9:44	6.50
	Finish	11:50	6.51

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-5			Well OB-6		
Date	Time	DTW	Date	Time	DTW
2/11/88			2/11/88		
Start	9:53	7.66	Start	9:56	7.05
	11:54	7.64		11:57	7.03
	13:54	7.61		13:57	7.01
	15:57	7.61		16:00	6.99
	17:47	7.61		17:50	6.99
	19:52	7.63		19:56	7.00
	21:55	7.67		21:59	6.97
	23:51	7.59		23:54	6.97
2/12/88			2/12/88		
	1:48	7.59		1:53	6.88
	3:48	7.39		3:52	6.70
	5:45	7.35		5:49	6.58
	7:48	7.34		7:51	6.62
	9:45	7.32		9:48	6.63
Finish	11:51	7.33	Finish	11:56	6.64

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-7			Well OB-8		
Date	Time	DTW	Date	Time	DTW
2/11/88			2/11/88		
Start	9:57	5.92	Start	9:58	4.87
	11:58	5.91		11:59	4.85
	13:58	5.88		13:59	4.81
	16:01	5.88		16:03	4.82
	17:51	5.87		17:52	4.81
	19:58	5.89		20:00	4.83
	22:01	5.85		22:02	4.76
	23:55	5.83		23:56	4.76
2/12/88			2/12/88		
	1:54	5.72		1:55	4.60
	3:53	5.38		3:55	4.23*
	5:50	5.30		5:52	4.38
	7:52	5.36		7:53	4.37
	9:48	5.39		9:49	4.39
Finish	11:57	5.41	Finish	11:59	4.38

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-9

Date	Time	DTW
2/11/88		
Start	9:55	6.28
	11:56	6.27
	13:56	6.23
	15:59	6.24
	17:49	6.25
	19:55	6.26
	21:58	6.21
	23:53	6.19
2/12/88		
	1:51	6.11
	3:51	5.96
	5:47	5.89
	7:50	5.89
	9:47	5.88
Finish	11:54	5.89

Well OB-10

Date	Time	DTW
2/11/88		
Start	9:54	6.72
	11:55	6.70
	13:55	6.67
	15:58	6.66
	17:48	6.67
	19:54	6.69
	21:56	6.65
	23:52	6.65
2/12/88		
	1:50	6.58
	3:50	6.46
	5:46	6.39
	7:48	6.42
	9:46	6.40
Finish	11:53	6.41

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-16			Well OB-21		
Date	Time	DTW	Date	Time	DTW
2/11/88			2/11/88		
Start	10:05	8.78	Start	10:04	7.73
	12:08	8.77		12:05	7.71
	14:06	8.75		14:04	7.68
	16:07	8.76		16:09	7.67
	17:59	8.77		17:58	7.68
	20:07	8.74		20:06	7.69
	22:10	8.75		22:08	7.66
2/12/88			2/12/88		
	0:03	8.72		0:02	14.4
	2:02	8.65		2:01	14.41*
	4:04	8.62		4:03	14.36*
	5:59	8.61		5:57	10.15
	8:02	8.67		8:00	10.47
	9:56	8.63		9:56	10.15
Finish	12:09	8.58	Finish	12:07	10.21

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-24

Date	Time	DTW
2/11/88		
Start	10:00	4.81
	12:00	4.78
	14:00	4.72
	16:04	4.73
	17:53	4.75
	20:01	4.74
	22:03	4.7
	23:57	4.65
2/12/88		
	1:56	4.53
	3:56	4.35
	5:53	4.26
	7:54	4.27
	9:51	4.26
Finish	12:01	4.31

Well OB-25

Date	Time	DTW
2/11/88		
Start	9:49	4.3
	11:48	4.26
	13:49	4.24
	15:52	4.25
	17:43	4.26
	19:46	4.27
	21:48	4.2
	23:47	4.19
2/12/88		
	1:42	4.04*
	3:42	3.89*
	5:42	3.8
	7:41	3.77
	9:40	3.75
Finish	11:46	3.76

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-27

Date	Time	DTW
2/11/88		
Start	9:47	7.17
	11:47	7.15
	13:47	7.12
	15:50	7.13
	17:42	7.12
	19:45	7.20
	21:44	7.16
	23:46	7.08
2/12/88		
	1:41	6.99*
	3:41	7.08
	5:41	6.89
	7:40	6.87
	9:39	6.82
Finish	11:44	6.79

Well OB-29

Date	Time	DTW
2/11/88		
Start	9:44	10.28
	11:44	10.26
	13:45	10.23
	15:48	10.25
	17:38	10.24
	19:41	10.25
	21:41	10.20
	23:43	10.20
2/12/88		
	1:38	- -
	3:38	- -
	5:38	- -
	7:39	- -
	9:37	- -
Finish	11:41	- -

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

- - Indicates well submerged and inaccessable

Tidal Fluctuation Study, Columbia Aquifer
New Castle Spill Site

Well OB-30

Date	Time	DTW
2/11/88		
Start	9:42	13.43
	11:42	13.42
	13:43	13.38
	15:46	13.46
	17:37	13.41
	19:39	13.50
	21:39	13.36
	23:41	13.35
2/12/88		
	1:36	13.28
	3:37	13.32
	5:36	13.27
	7:37	13.25
	9:35	13.23
Finish	11:36	13.24

Well PH

Date	Time	DTW
2/11/88		
Start	9:46	14.18
	11:45	14.17
	13:46	14.20
	15:49	14.19
	17:40	14.14
	19:43	14.06
	21:43	14.00
	23:45	13.97
2/12/88		
	1:39	13.89
	3:39	13.79
	5:39	13.61
	7:39	13.47
	9:37	13.37
Finish	11:42	13.34

Depth to water (DTW) given in feet below top of casing

* Indicates run off water flowing into well

Tidal Fluctuation Study , Columbia Aquifer
New Castle Spill Site

Well OB-11

Date	Time	DTW
2/11/88		
	9:30	8.55
	19:30	8.47
2/12/88		
	5:30	4.71

Well OB-12

Date	Time	DTW
2/11/88		
	9:30	9.15
	19:30	9.10
2/12/88		
	5:30	9.00

Well OB-28

Date	Time	DTW
2/11/88		
	9:30	7.39
	19:30	7.29
2/12/88		
	5:30	6.71

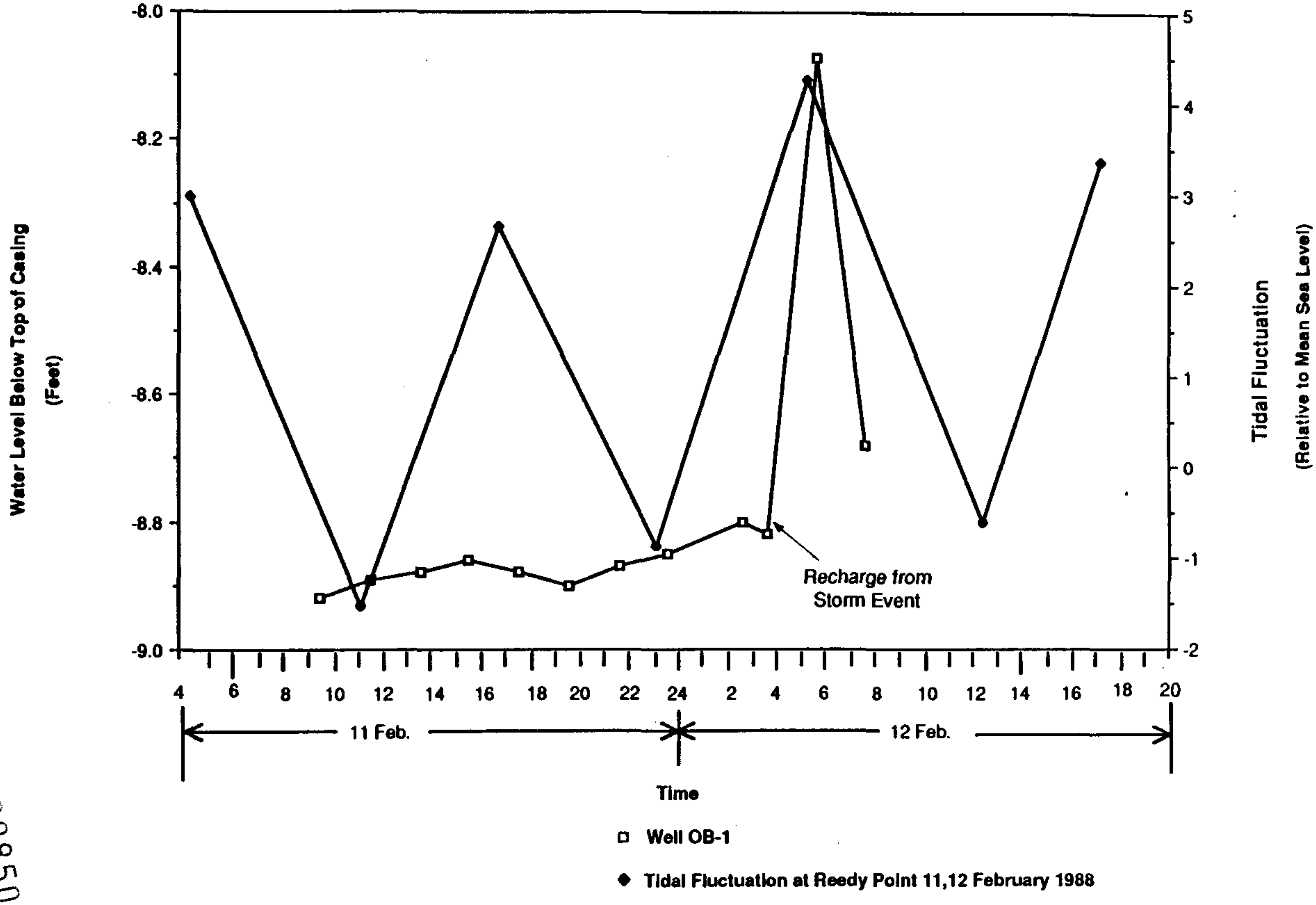
Depth to water (DTW) given in feet below top of casing

* Indicates well had run off water flowing into it

Wells OB - 11, OB - 12, OB - 28 were monitored by Hermit® data loggers, programming error resulted in insufficient data collection

Tidal Fluctuation Study

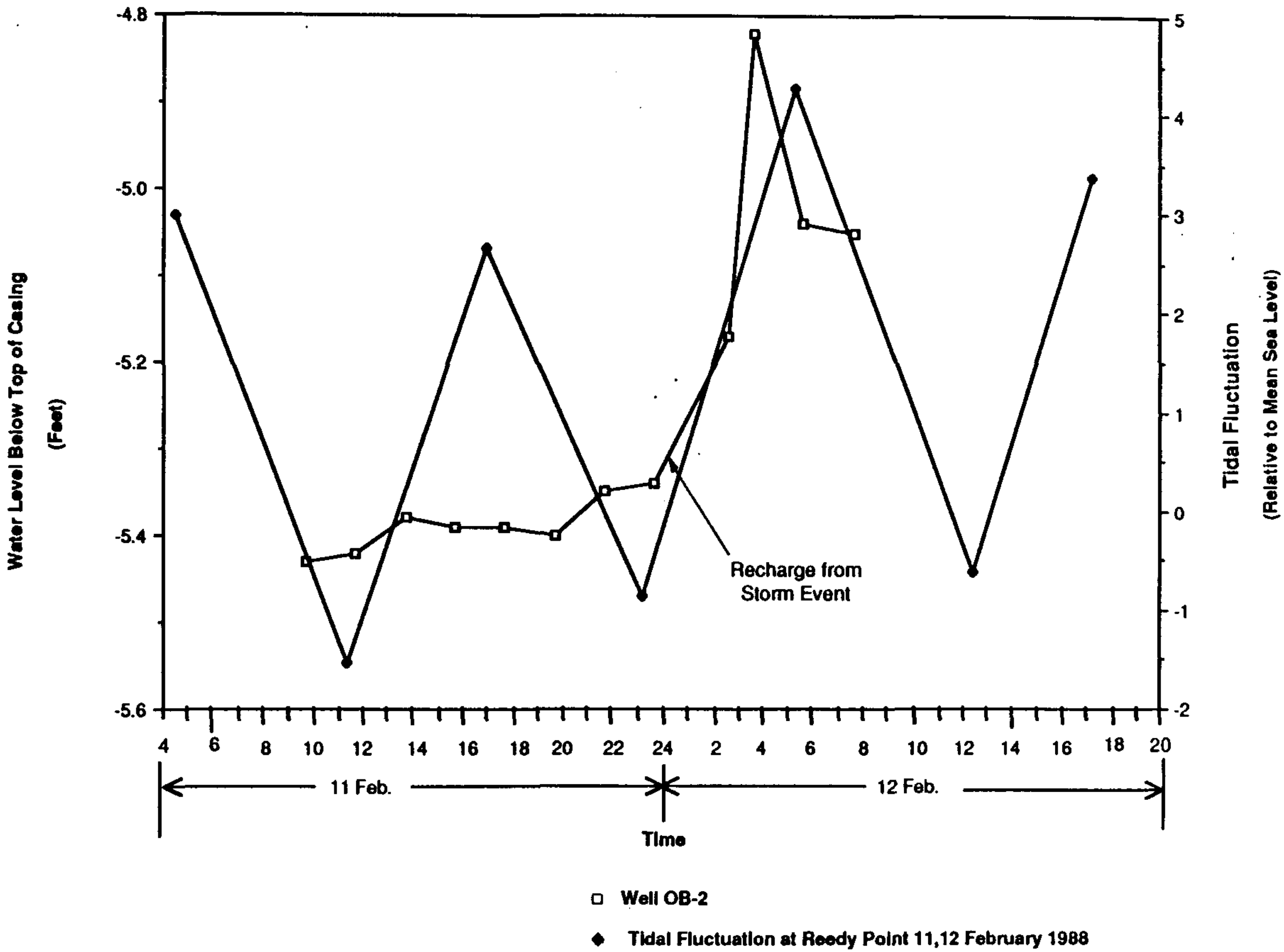
Well OB-1

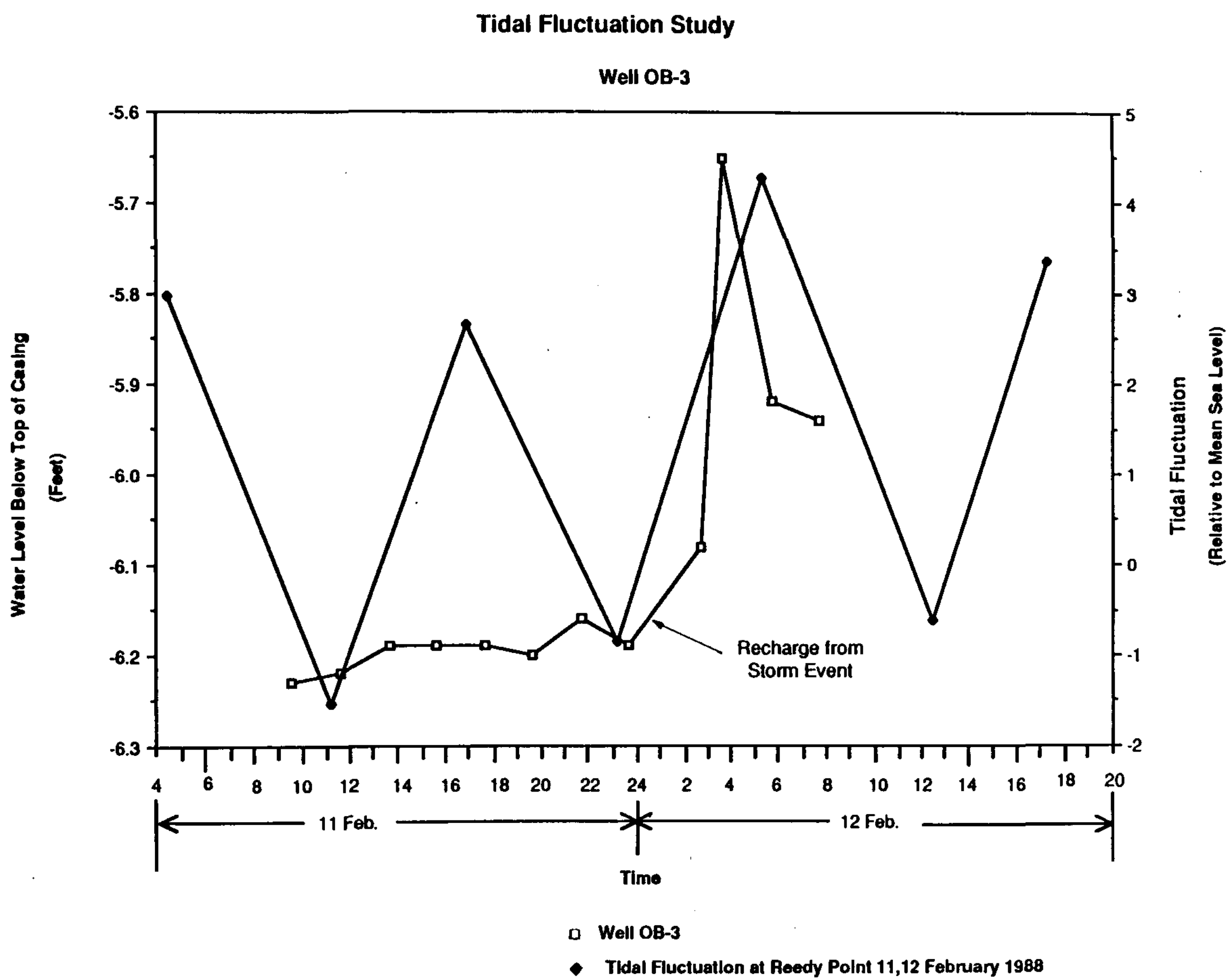


AR300850

Tidal Fluctuation Study

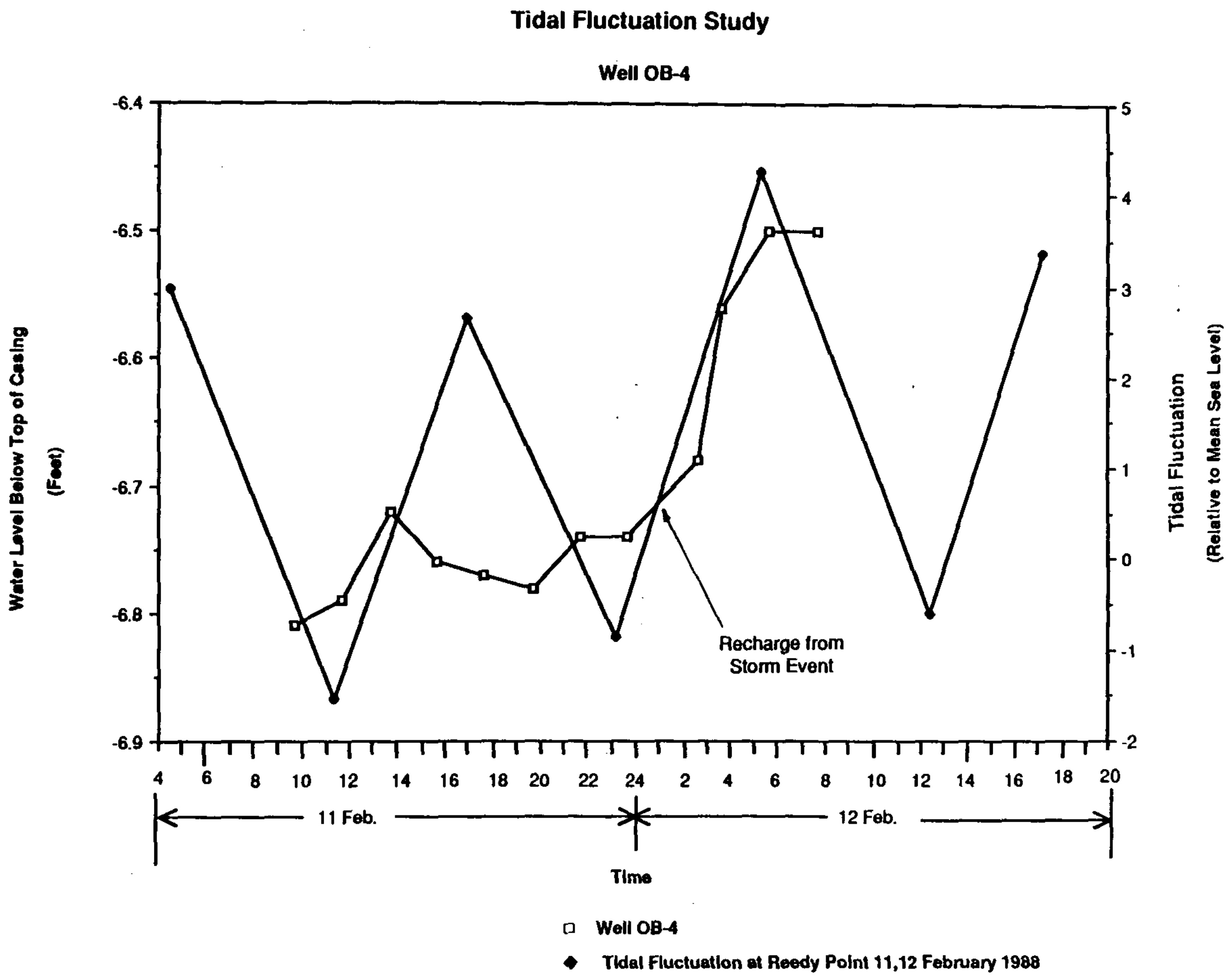
Well OB-2





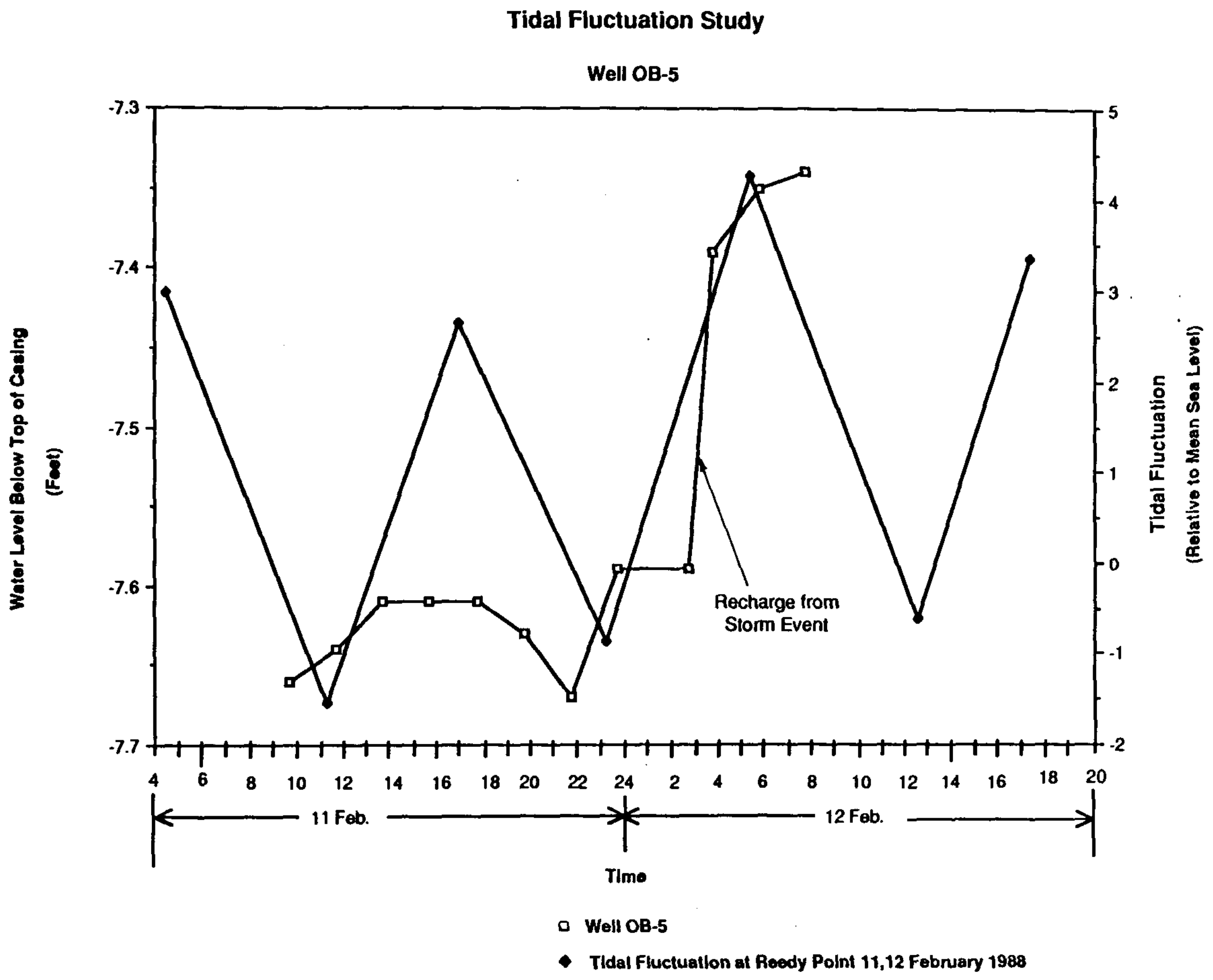
Tidal Fluctuation Study
Well OB-3
Water Level Below Top of Casing
(Feet)
-5.6
-5.7
-5.8
-5.9
-6.0
-6.1
-6.2
-6.3
Tidal Fluctuation
(Relative to Mean Sea Level)
5
4
3
2
1
0
-1
-2
Recharge from
Storm Event
4 6 8 10 12 14 16 18 20 22 24 2 4 6 8 10 12 14 16 18 20
11 Feb.
12 Feb.
Time
Well OB-3
Tidal Fluctuation at Reedy Point 11,12 February 1988

AR300852



Tidal Fluctuation Study
Well OB-4
Water Level Below Top of Casing
(Feet)
-6.4
-6.5
-6.6
-6.7
-6.8
-6.9
Tidal Fluctuation
(Relative to Mean Sea Level)
5
4
3
2
1
0
-1
-2
Recharge from
Storm Event
4 6 8 10 12 14 16 18 20 22 24 2 4 6 8 10 12 14 16 18 20
11 Feb.
12 Feb.
Time
Well OB-4
Tidal Fluctuation at Reedy Point 11,12 February 1988

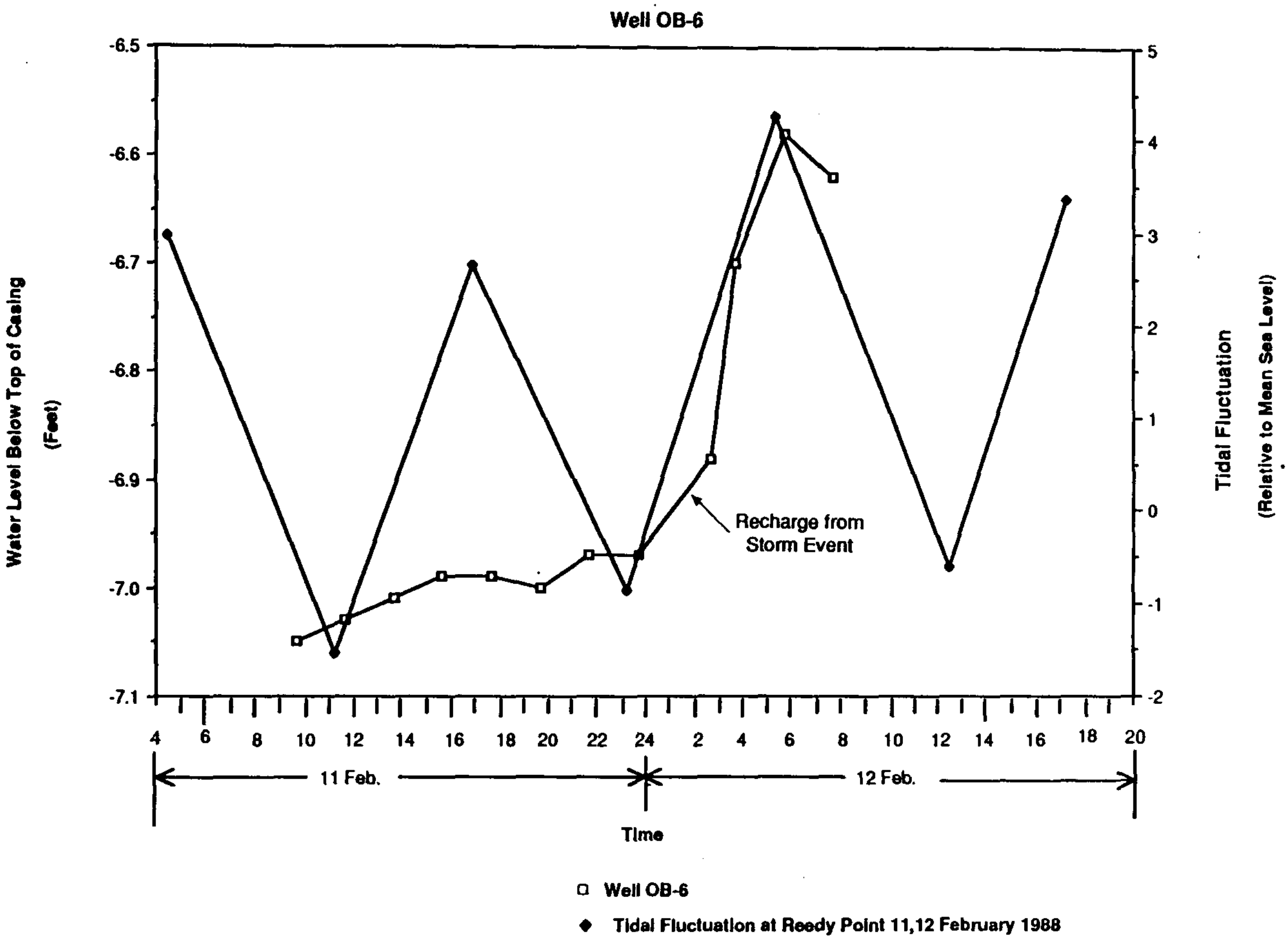
AR300853



Tidal Fluctuation Study
Well OB-5
Water Level Below Top of Casing
(Feet)
-7.3
-7.4
-7.5
-7.6
-7.7
Tidal Fluctuation
(Relative to Mean Sea Level)
5
4
3
2
1
0
-1
-2
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
11 Feb.
12 Feb.
Time
Recharge from
Storm Event
Well OB-5
Tidal Fluctuation at Reedy Point 11,12 February 1988

AR300854

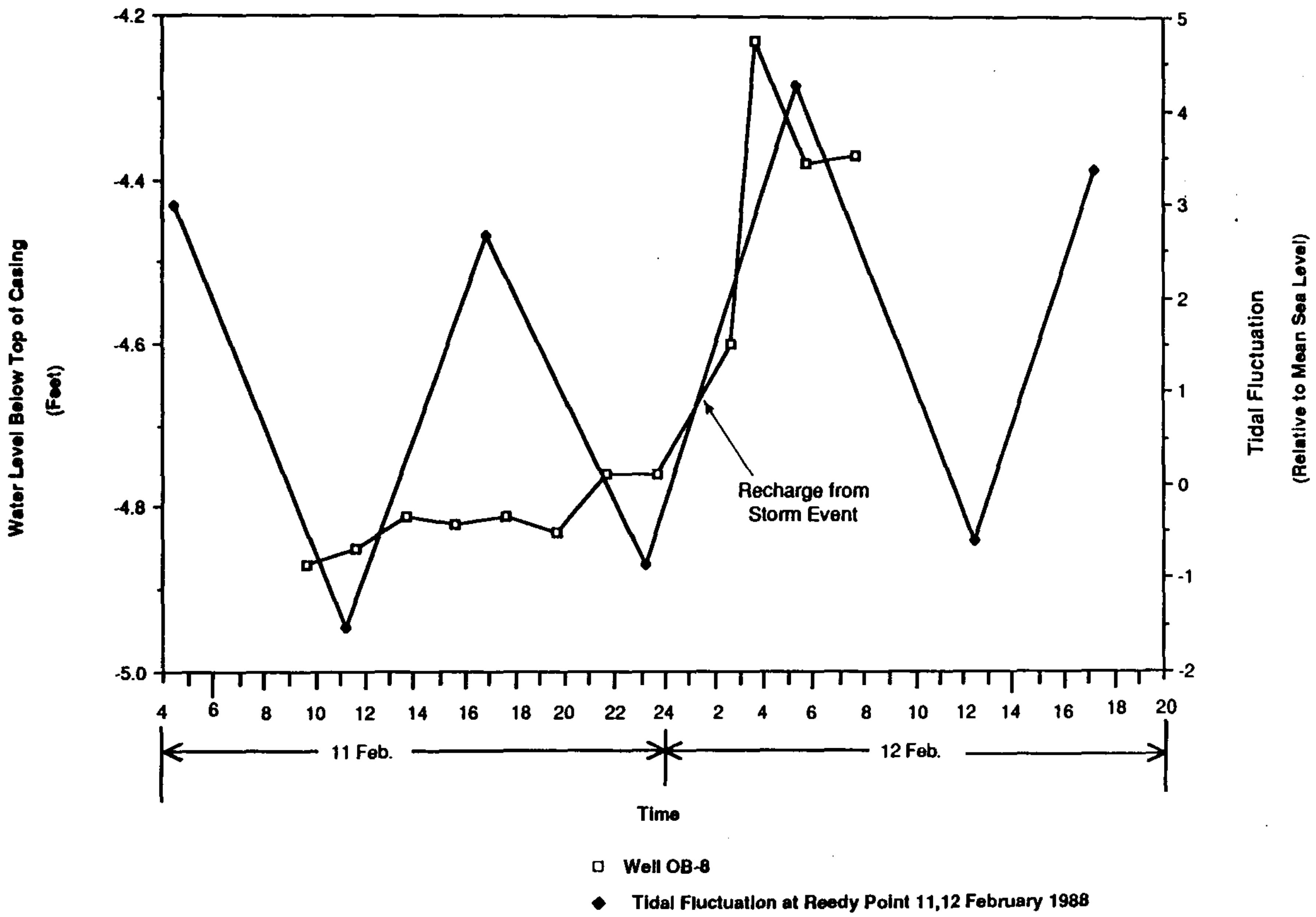
Tidal Fluctuation Study



AR300855

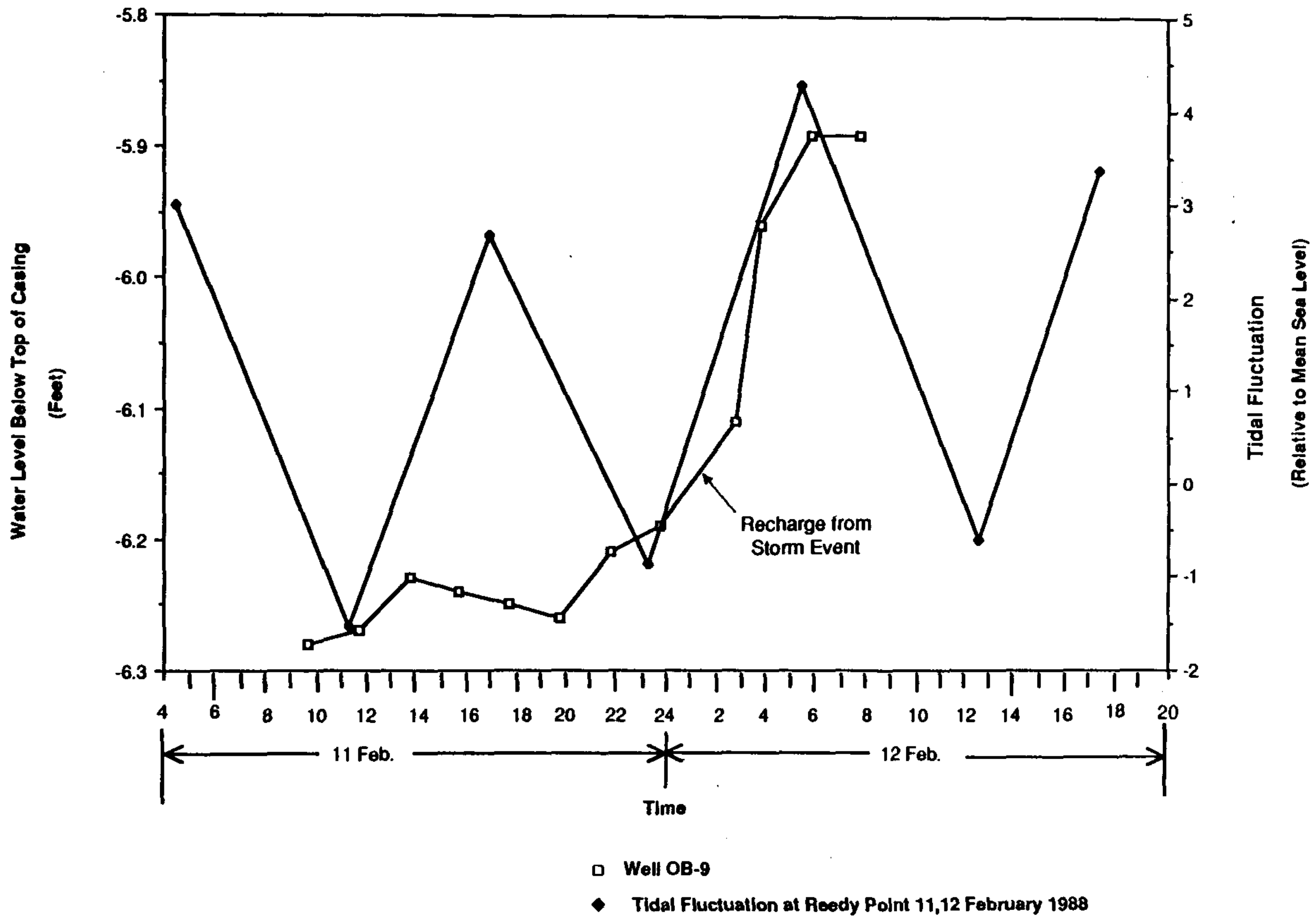
Tidal Fluctuation Study

Well OB-8



Tidal Fluctuation Study

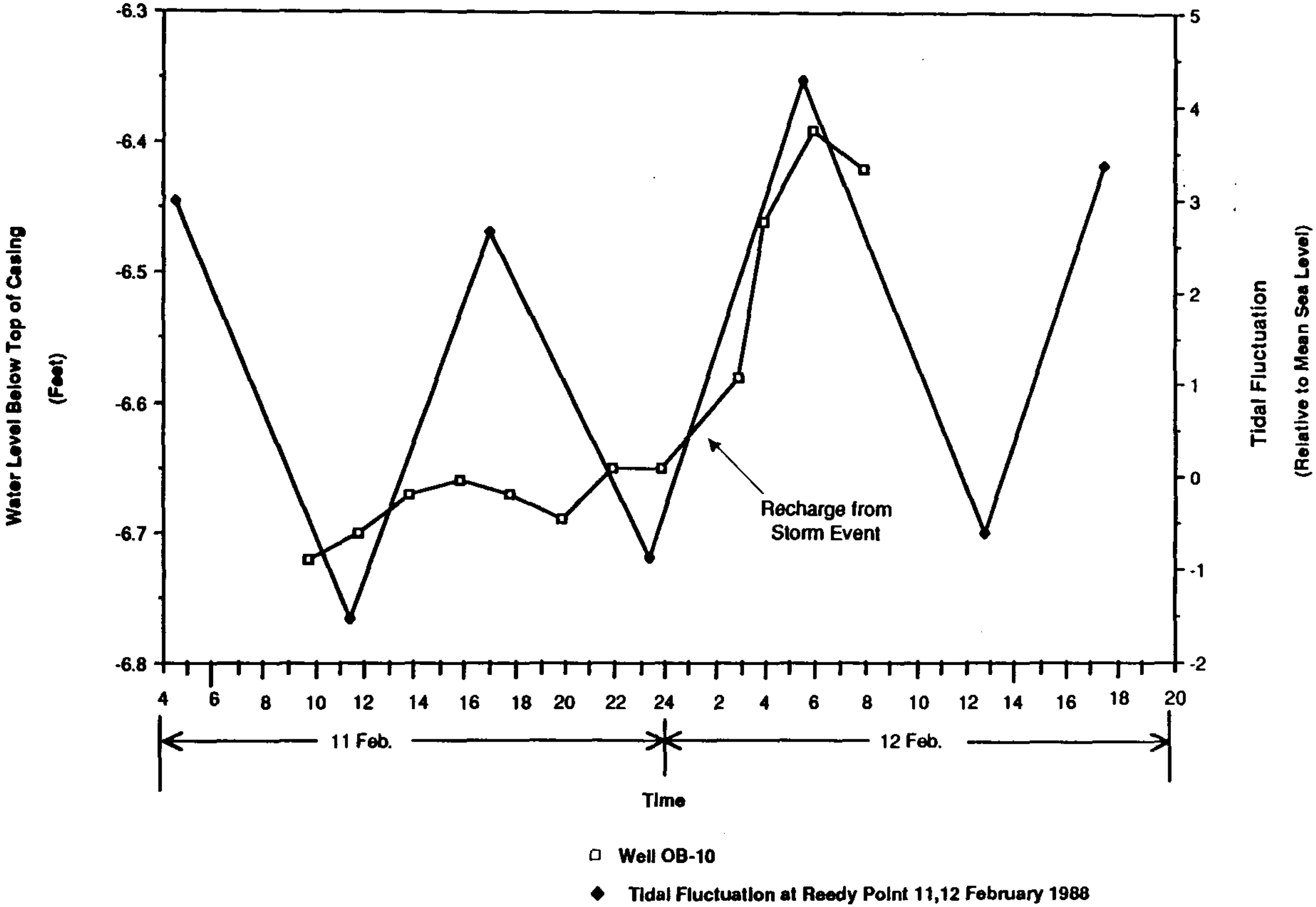
Well OB-9



AR300857

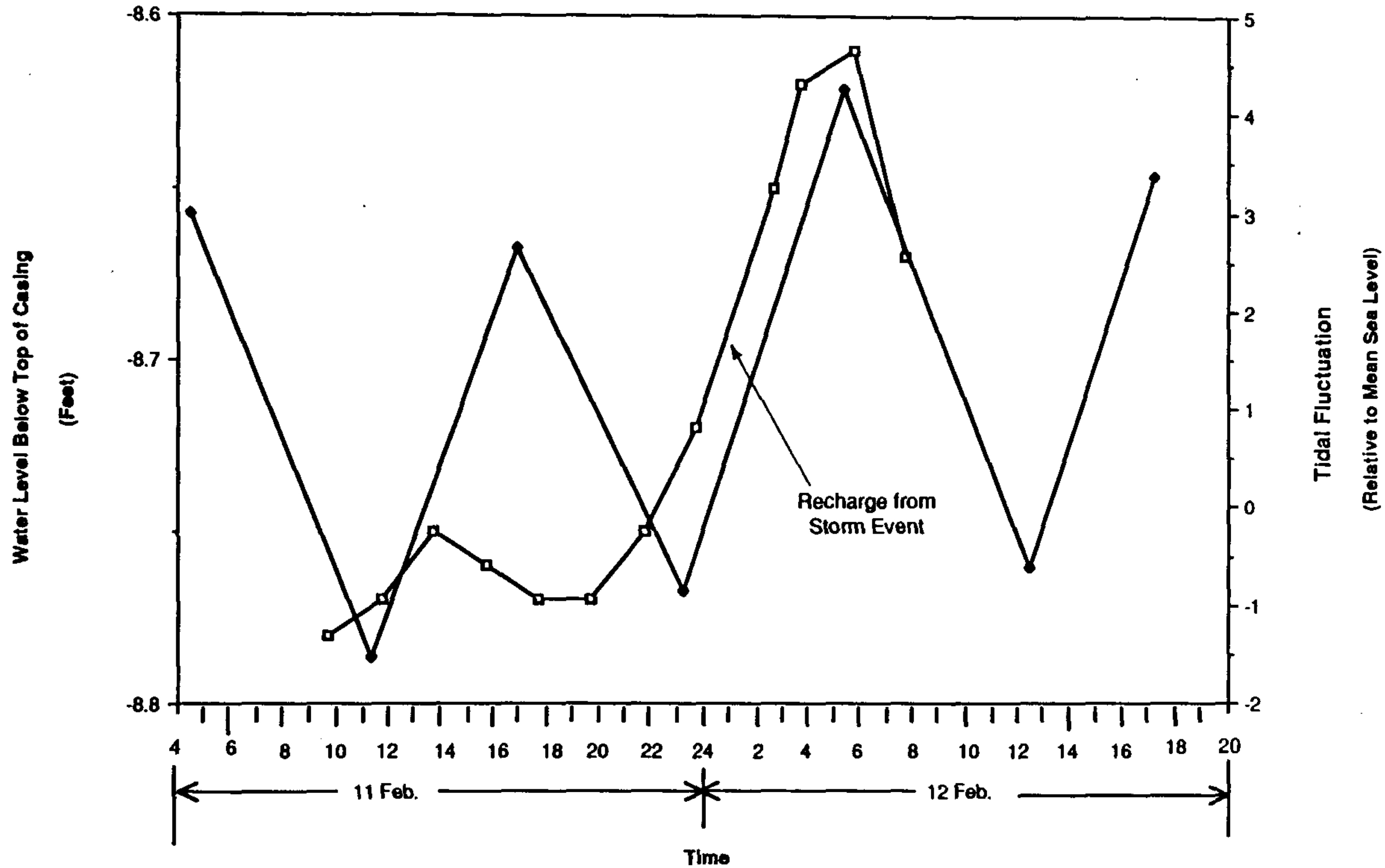
Tidal Fluctuation Study

Well OB-10



Tidal Fluctuation Study

Well OB-16



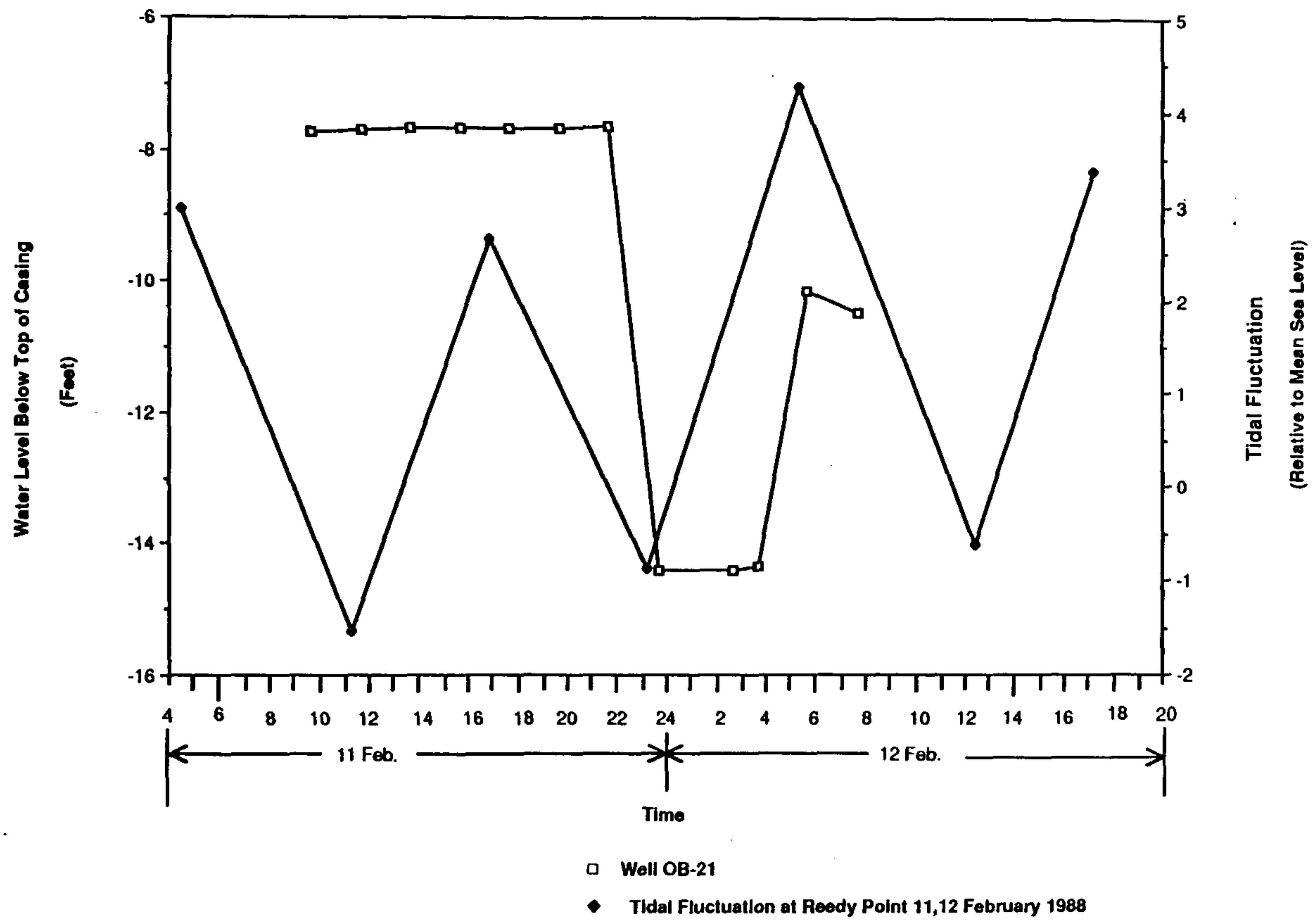
□ Well OB-16

◆ Tidal Fluctuation at Reedy Point 11,12 February 1988

AR300859

Tidal Fluctuation Study

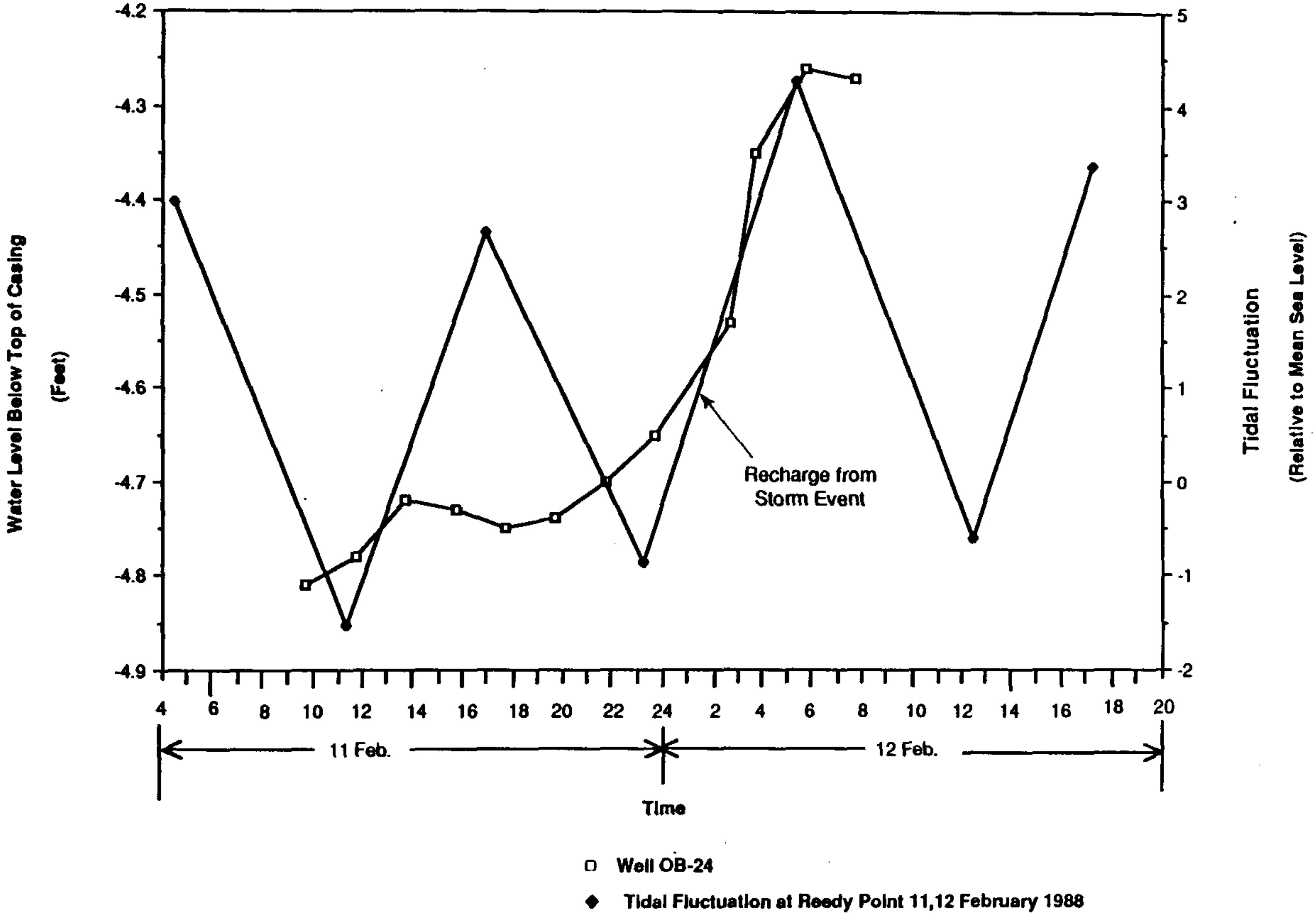
Well OB-21



AR300860

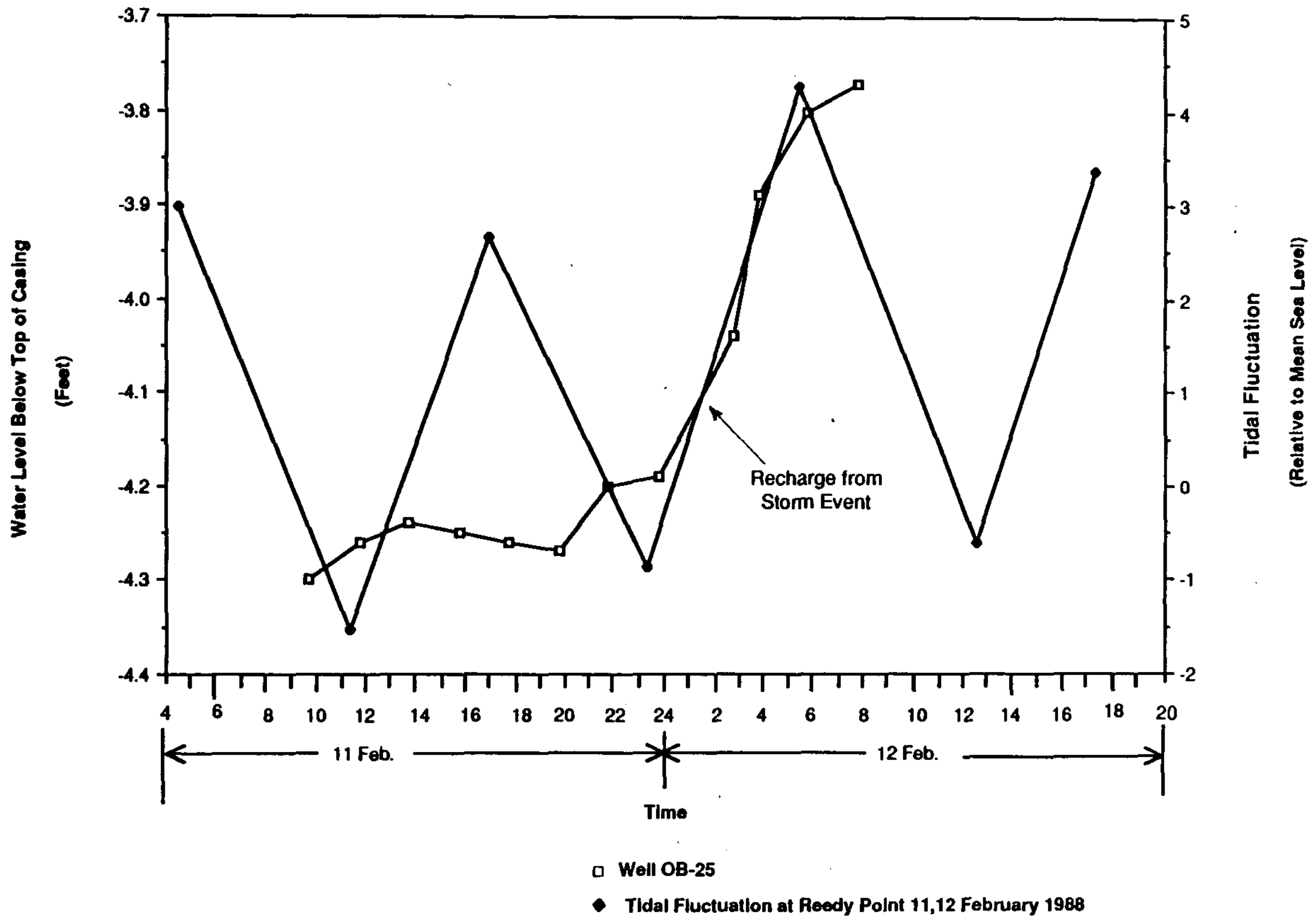
Tidal Fluctuation Study

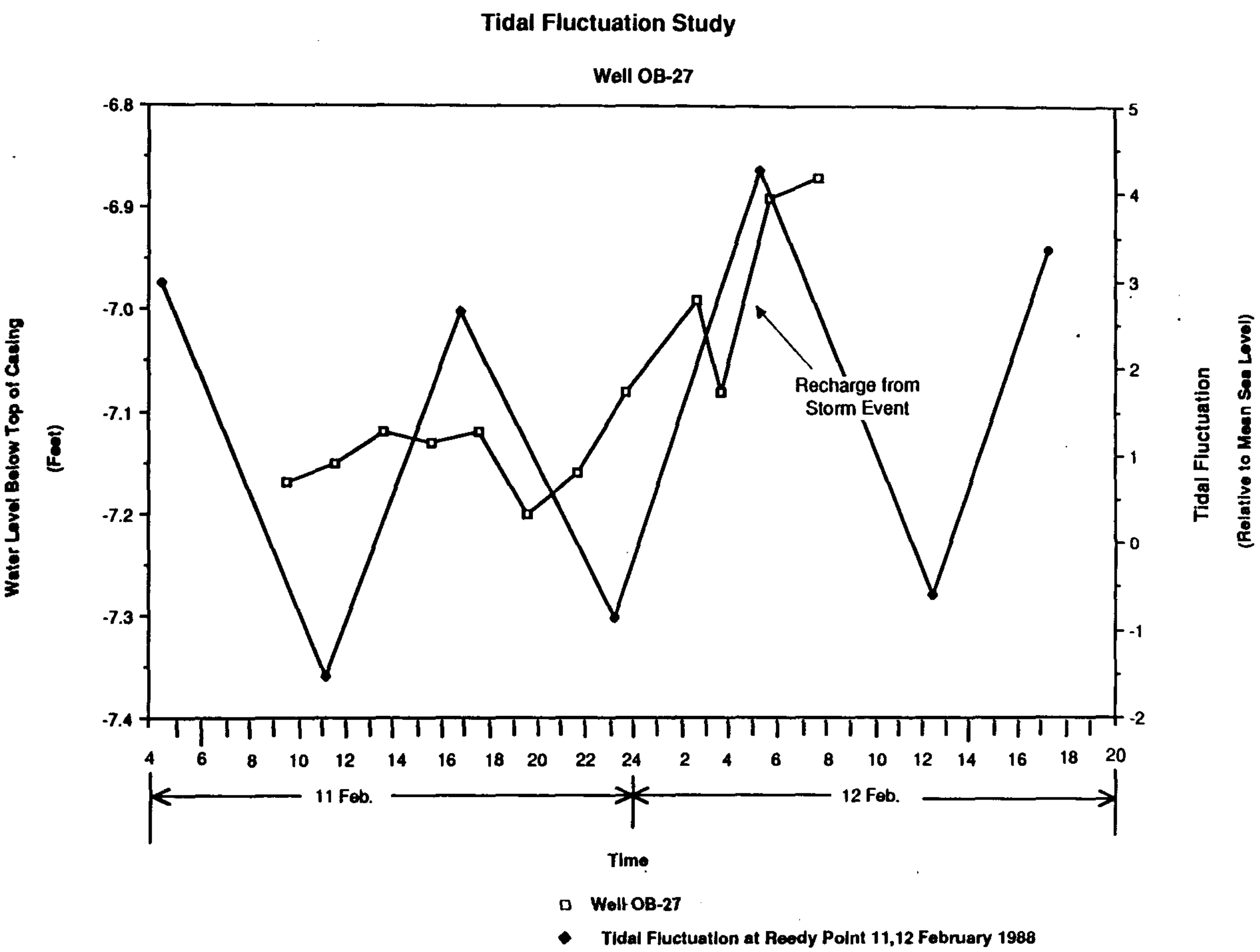
Well OB-24



Tidal Fluctuation Study

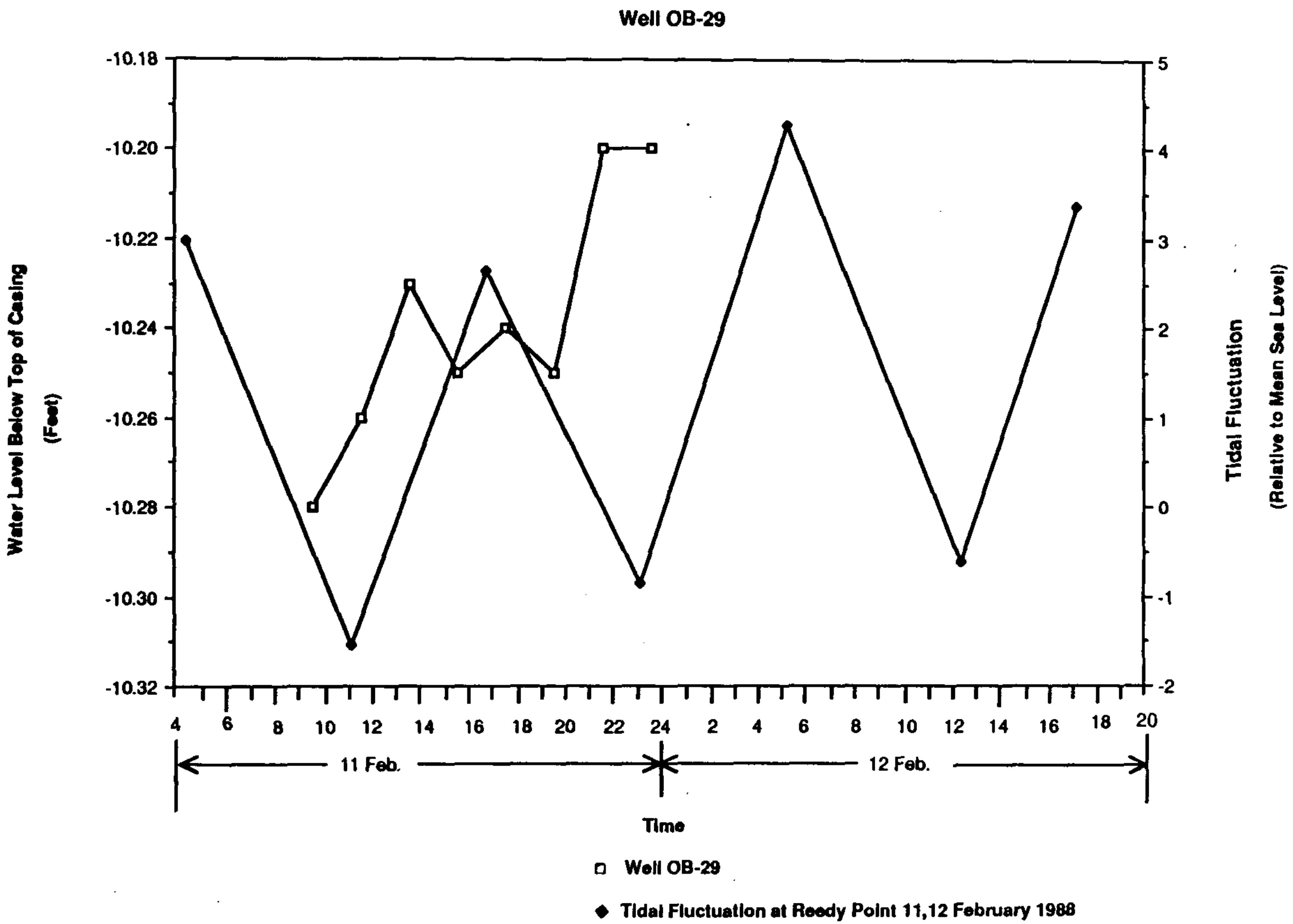
Well OB-25




Tidal Fluctuation Study
Well OB-27
Water Level Below Top of Casing
(Feet)
-6.8
-6.9
-7.0
-7.1
-7.2
-7.3
-7.4
Tidal Fluctuation
(Relative to Mean Sea Level)
5
4
3
2
1
0
-1
-2
Recharge from
Storm Event
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
11 Feb.
12 Feb.
Time
Well OB-27
Tidal Fluctuation at Reedy Point 11,12 February 1988

AR300863

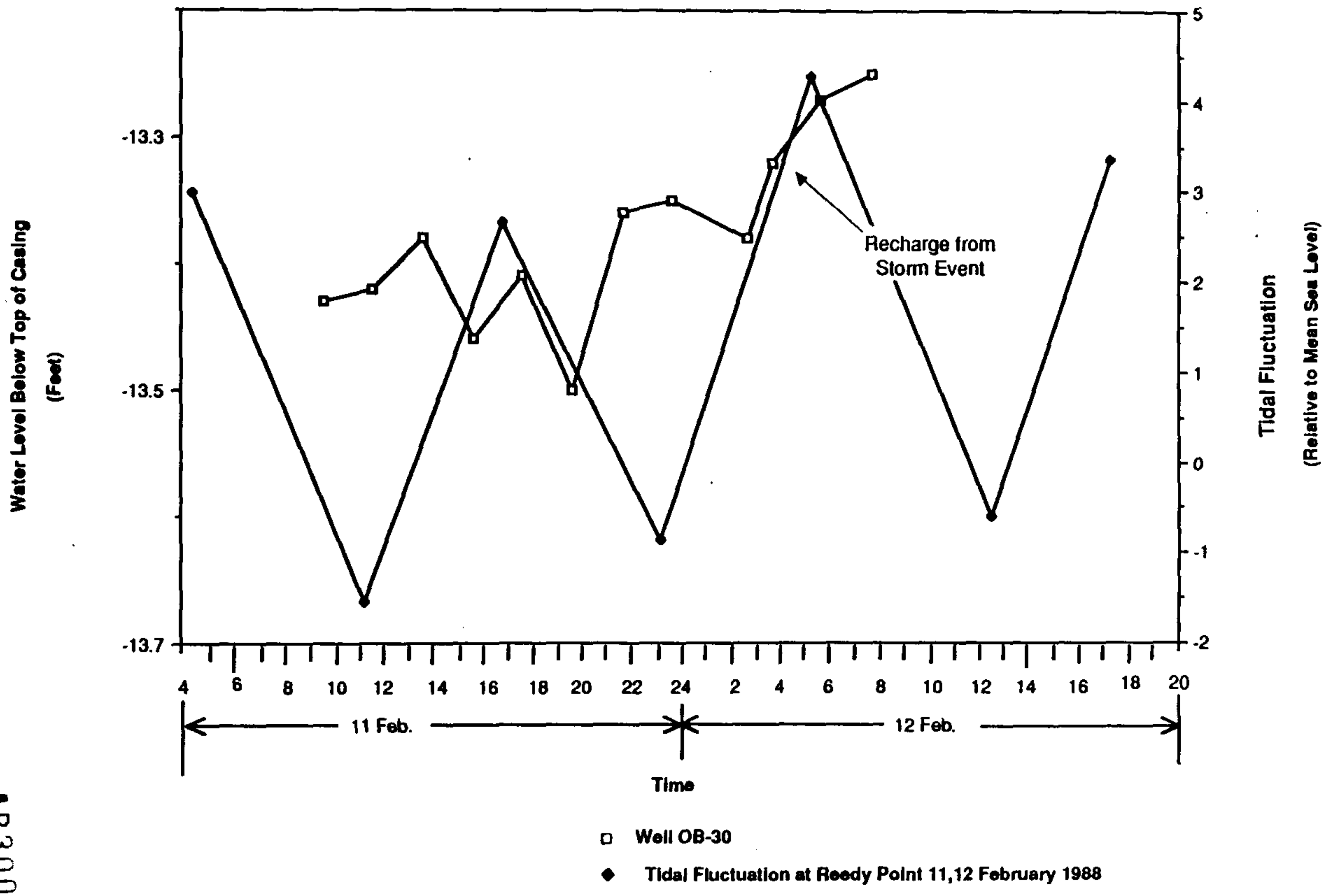
Tidal Fluctuation Study



AR300864

Tidal Fluctuation Study

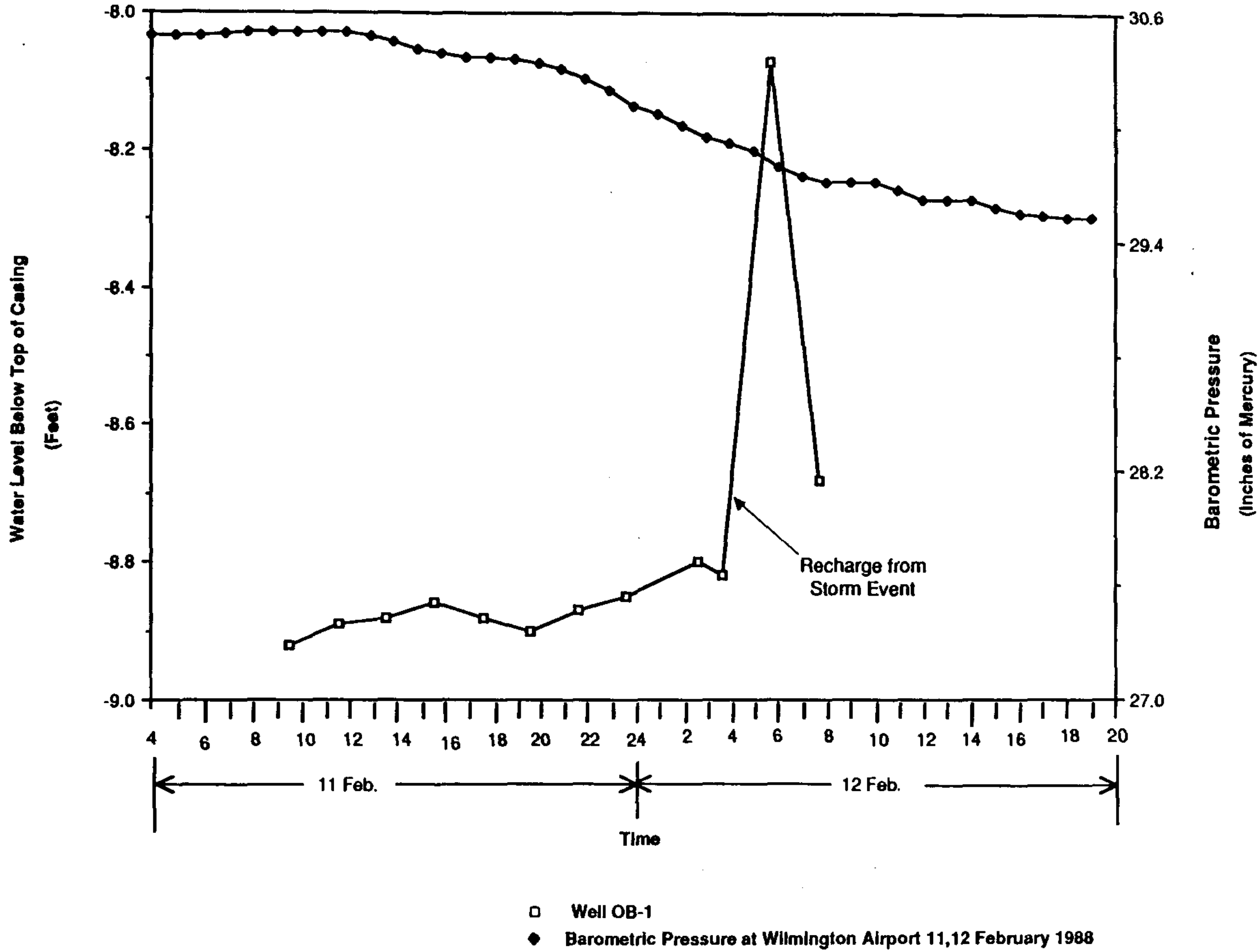
Well OB-30



AR300865

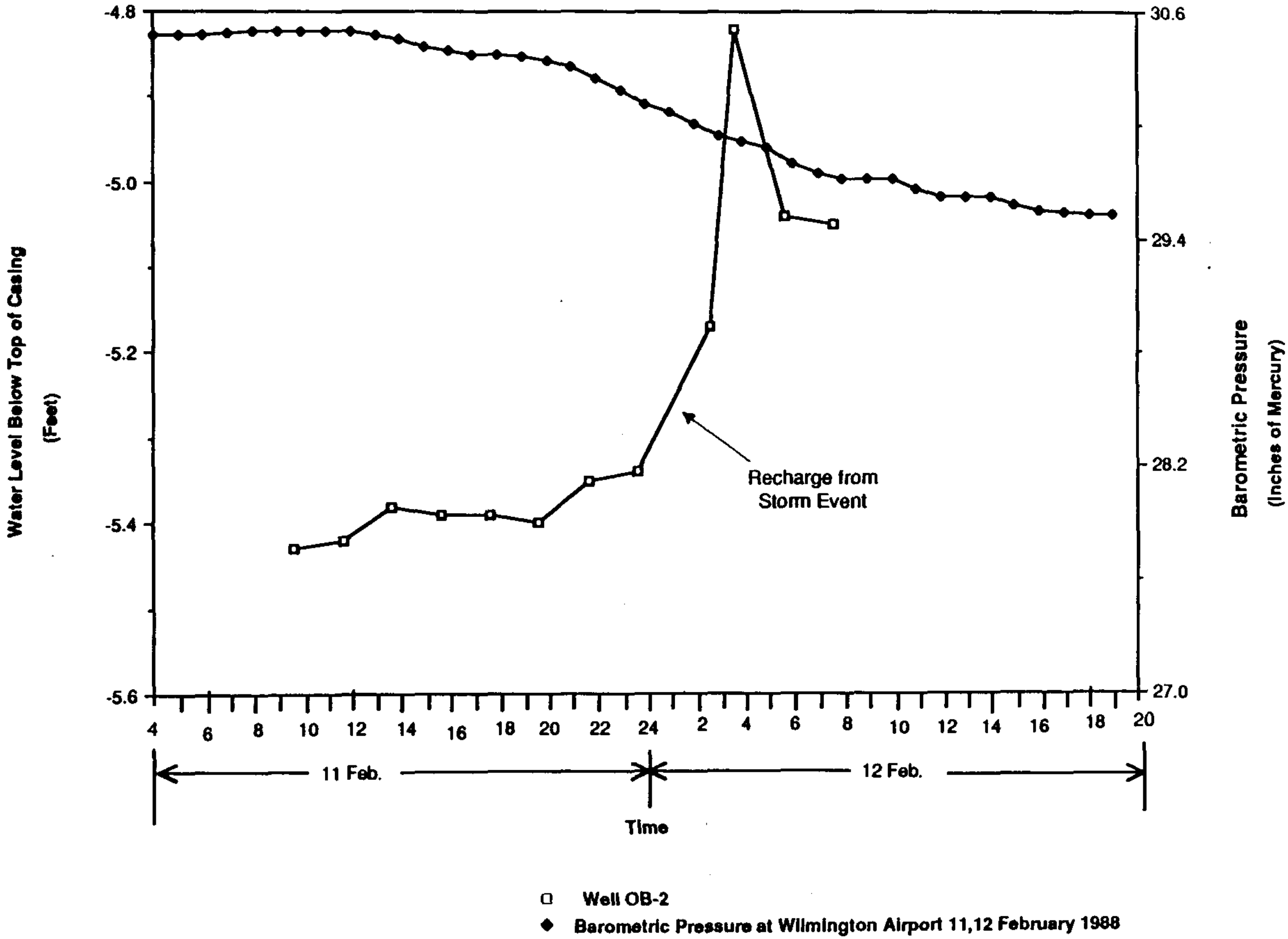
Barometric/Water Level Relationship

Well OB-1



Barometric/Water Level Relationship

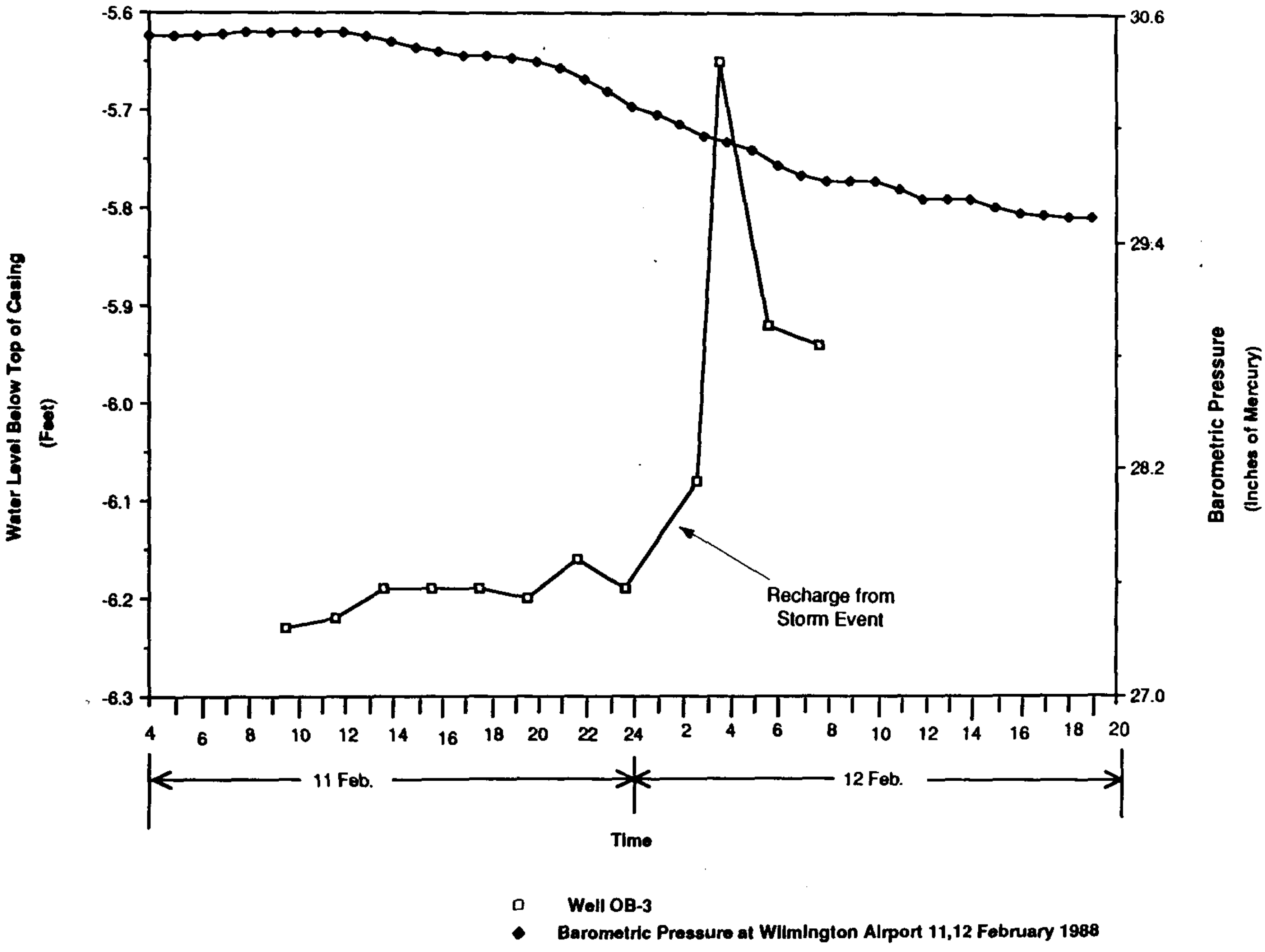
Well OB-2



AR300867

Barometric/Water Level Relationship

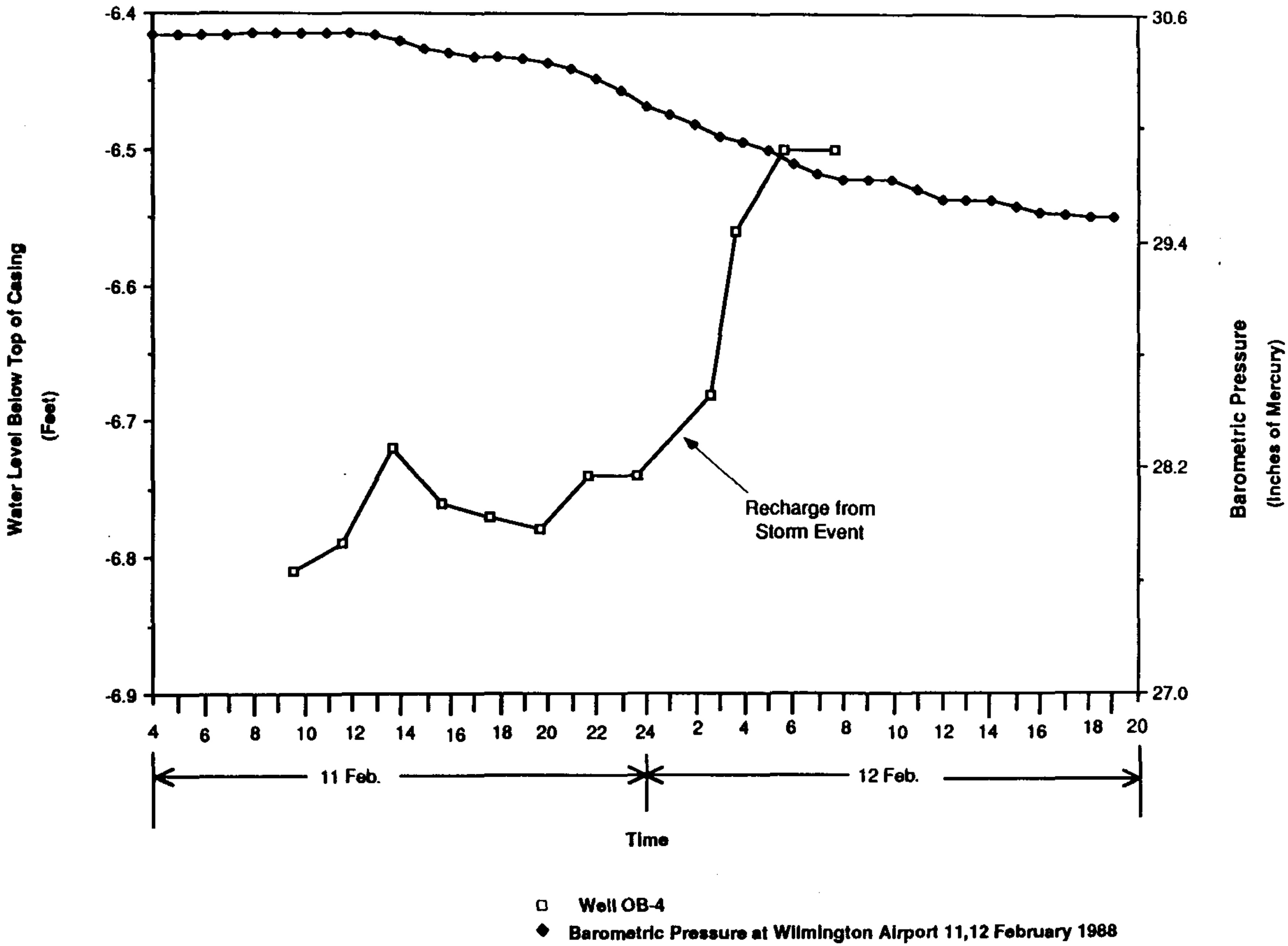
Well OB-3



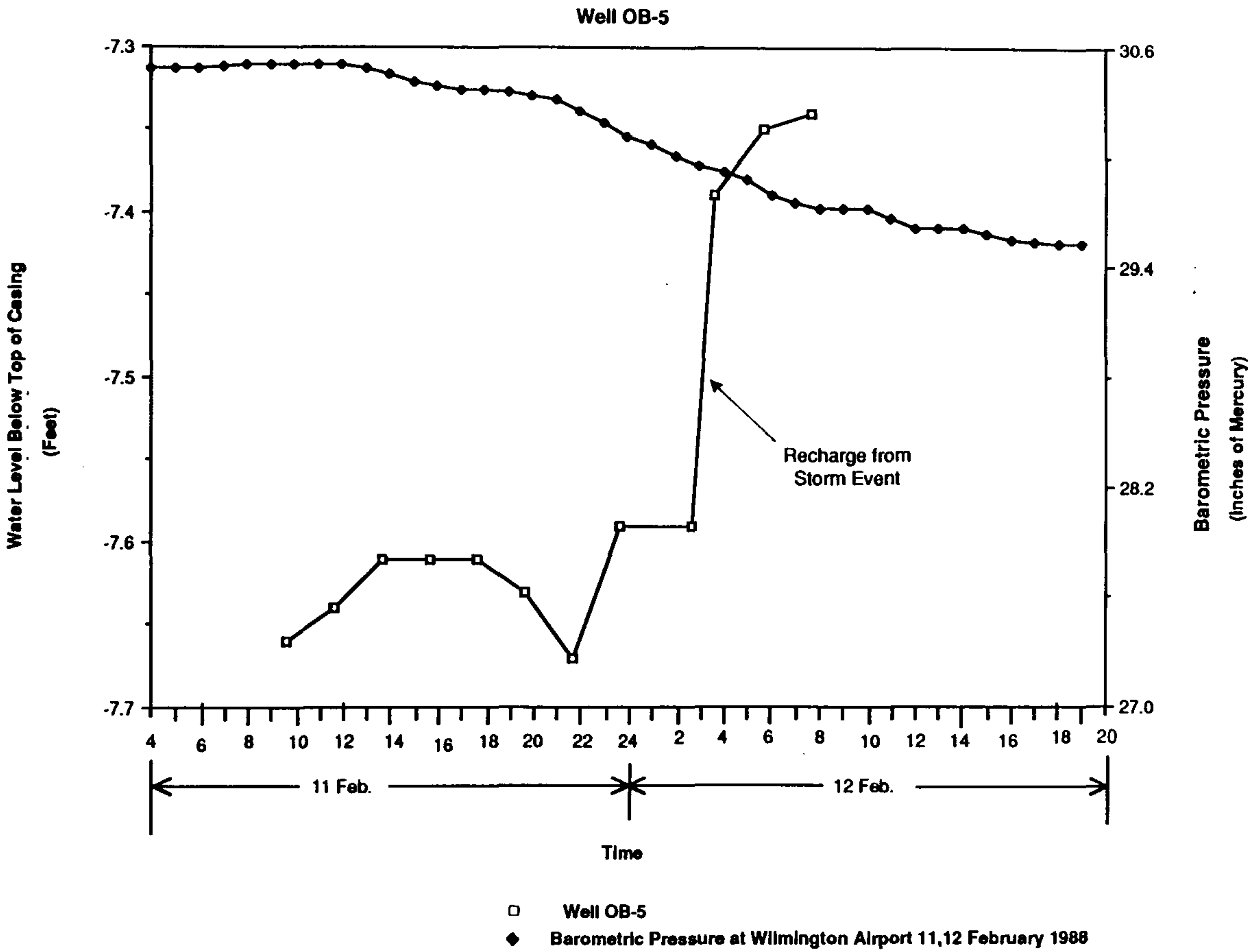
AR300868

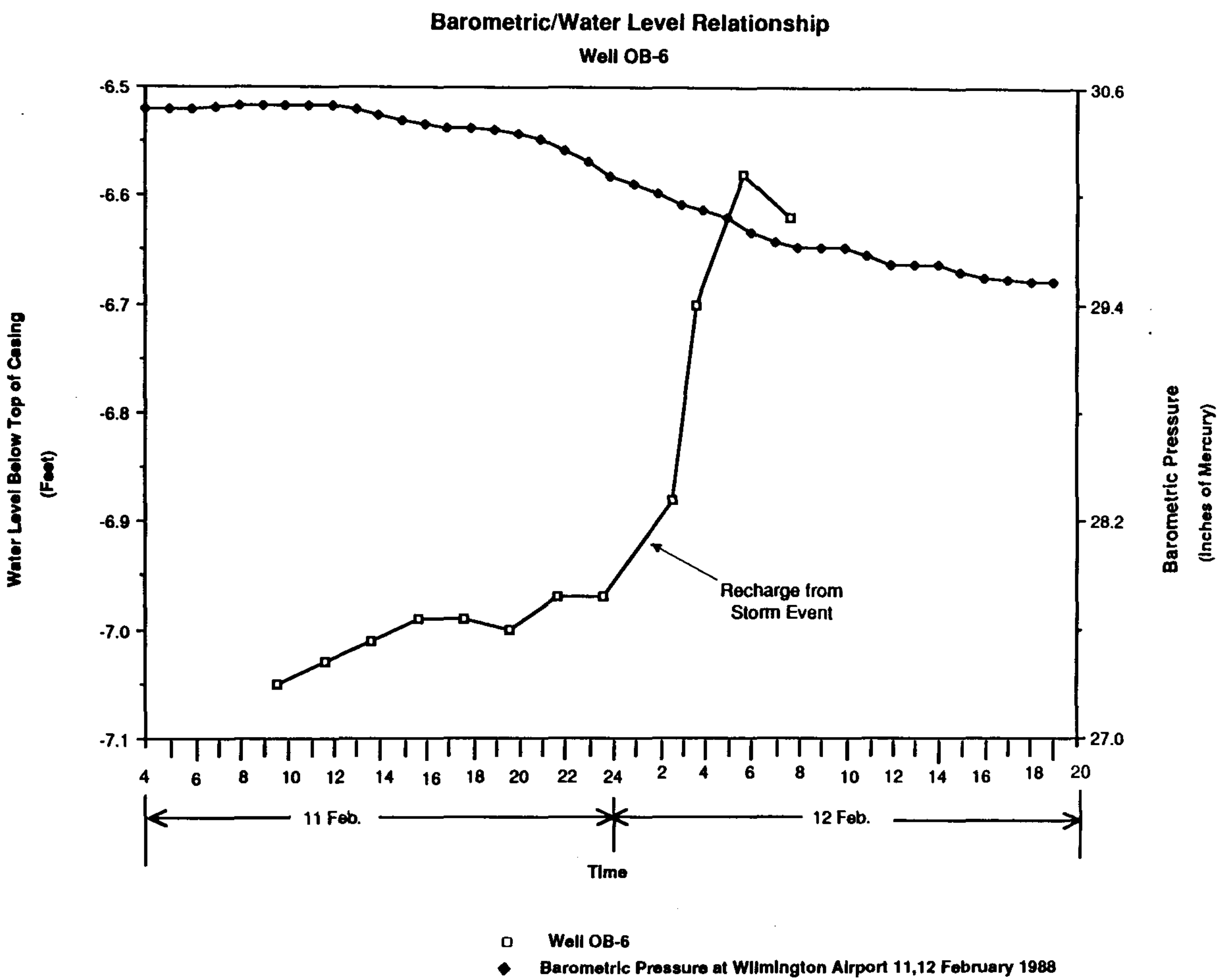
Barometric/Water Level Relationship

Well OB-4

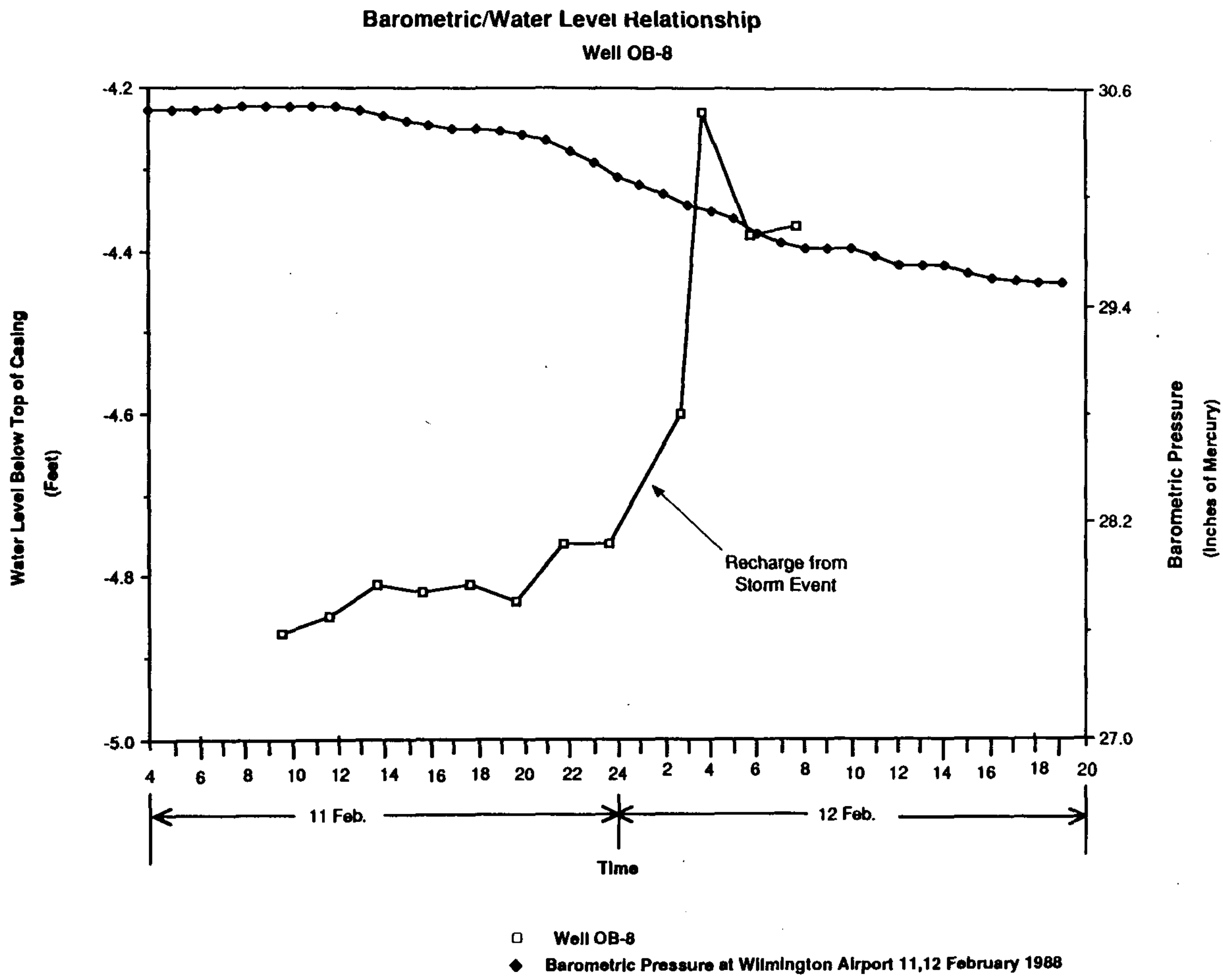


Barometric/Water Level Relationship




Barometric/Water Level Relationship
Well OB-6
Water Level Below Top of Casing (Feet)
-6.5
-6.6
-6.7
-6.8
-6.9
-7.0
-7.1
Barometric Pressure (Inches of Mercury)
30.6
29.4
28.2
27.0
4 6 8 10 12 14 16 18 20 22 24 2 4 6 8 10 12 14 16 18 20
11 Feb.
12 Feb.
Time
Recharge from Storm Event
Well OB-6
Barometric Pressure at Wilmington Airport 11,12 February 1988

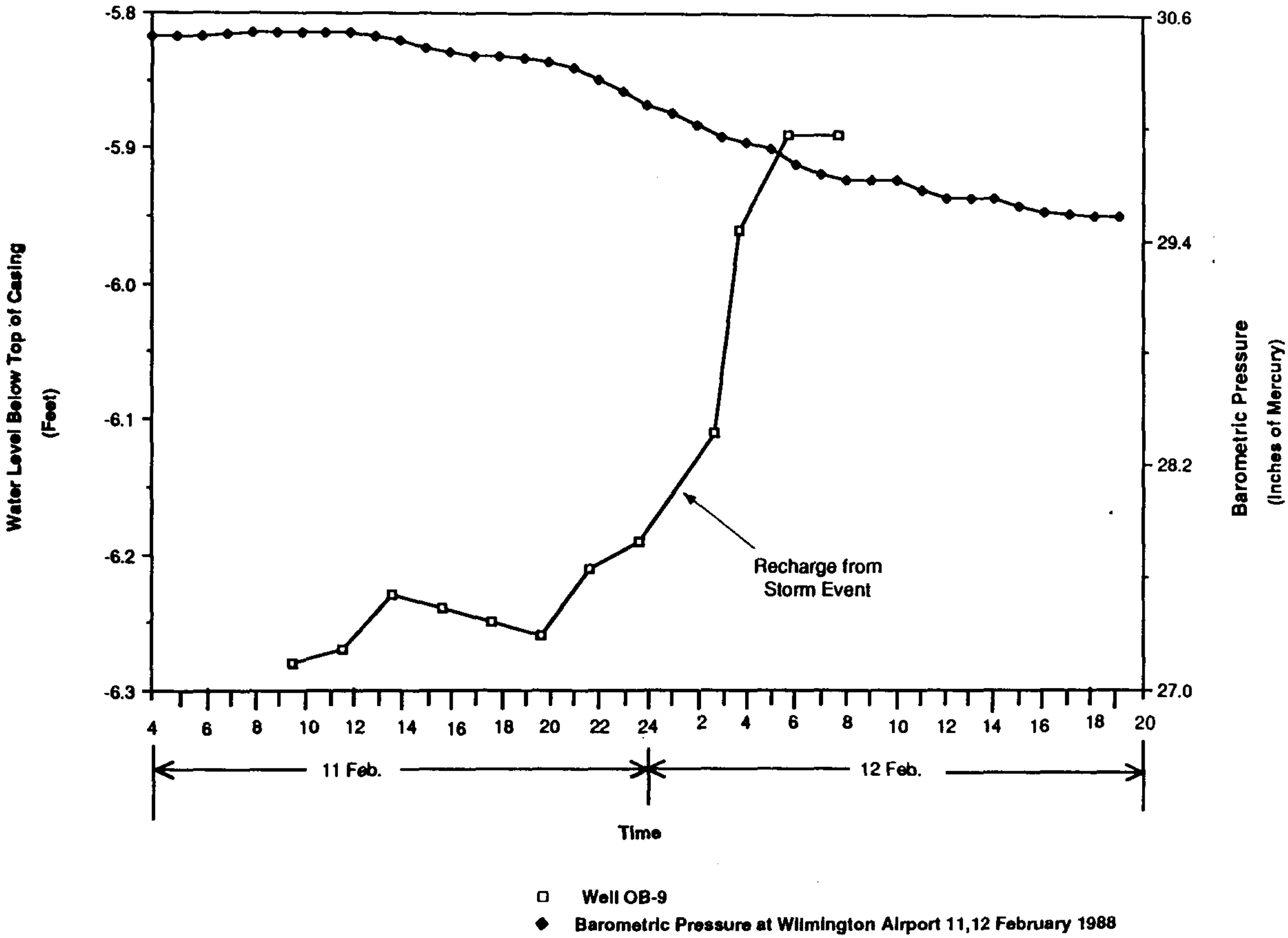
AR300871


Barometric/Water Level Relationship
Well OB-8
Water Level Below Top of Casing
(Feet)
-4.2
-4.4
-4.6
-4.8
-5.0
Barometric Pressure
(Inches of Mercury)
30.6
29.4
28.2
27.0
Recharge from
Storm Event
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
11 Feb.
12 Feb.
Time
Well OB-8
Barometric Pressure at Wilmington Airport 11,12 February 1988

AR300872

Barometric/Water Level Relationship

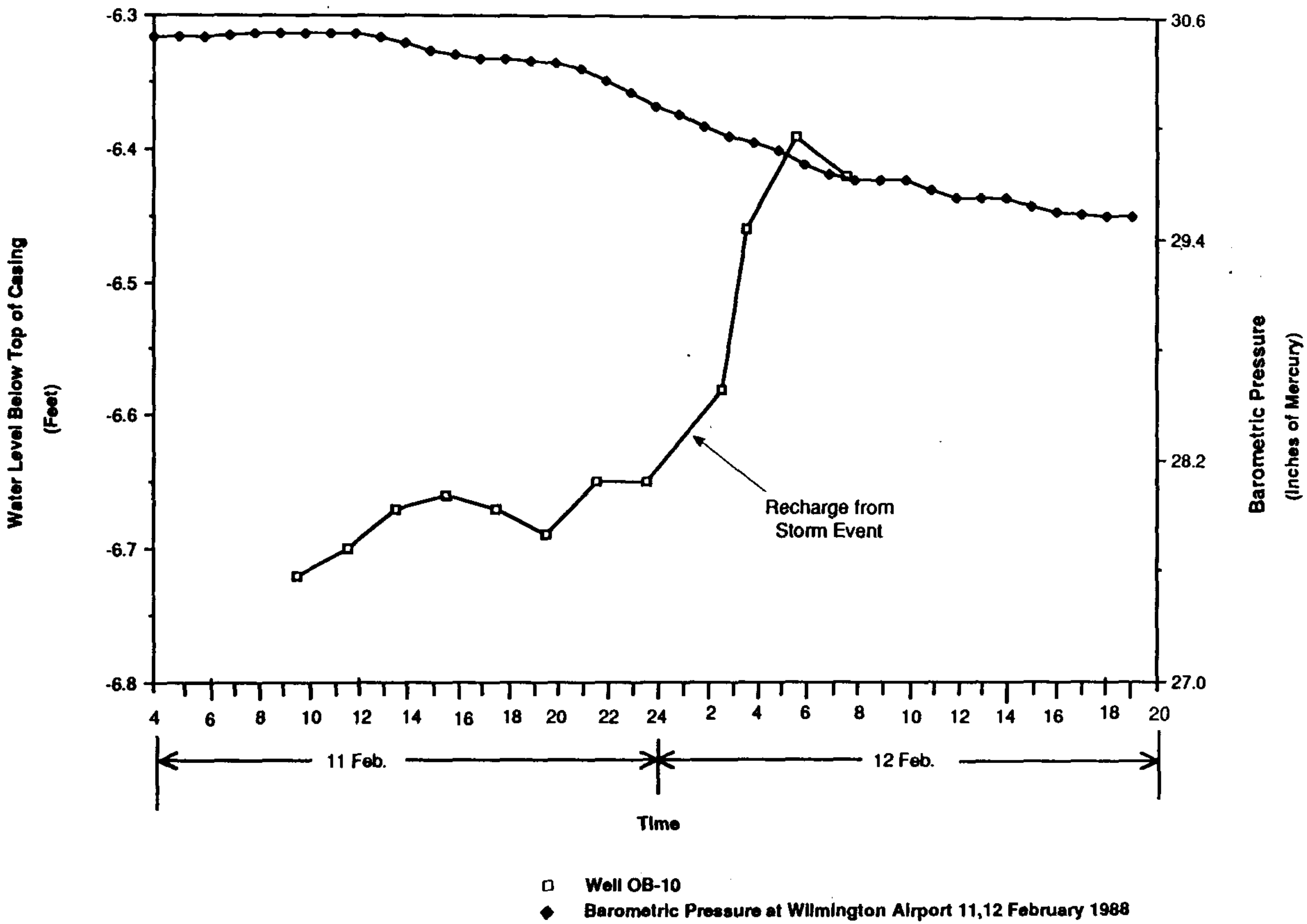
Well OB-9



AR300873

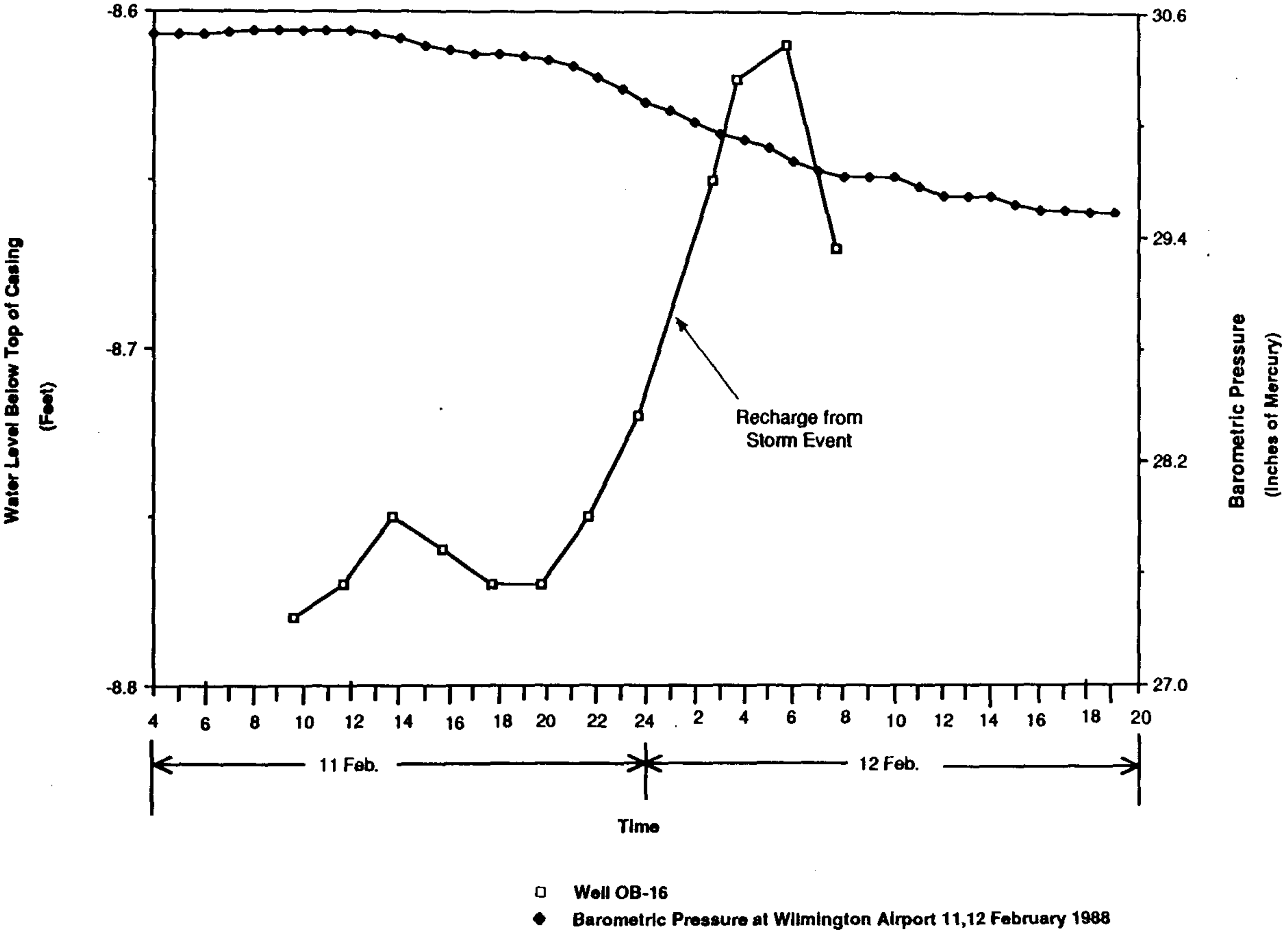
Barometric/Water Level Relationship

Well OB-10



Barometric/Water Level Relationship

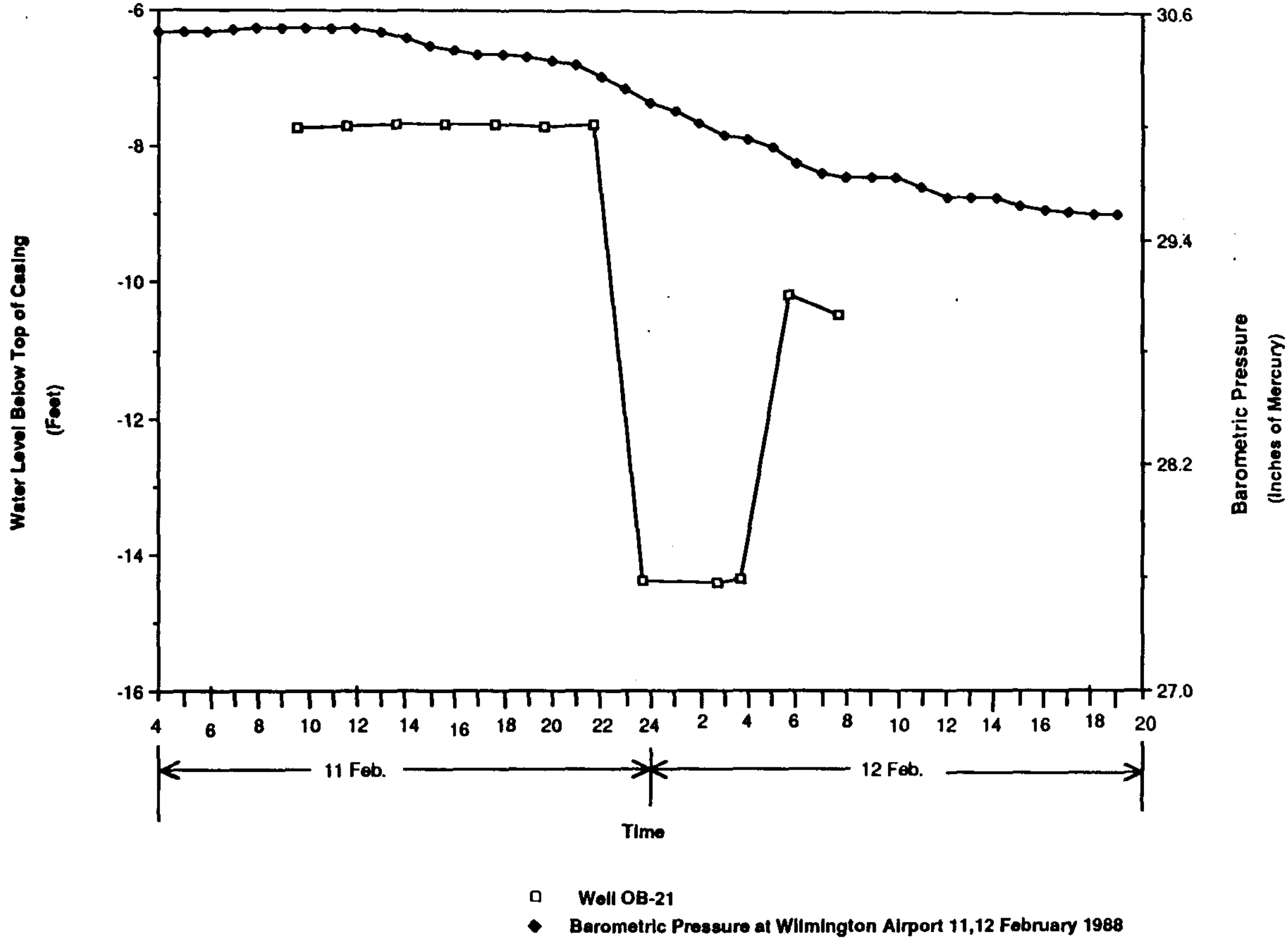
Well OB-16



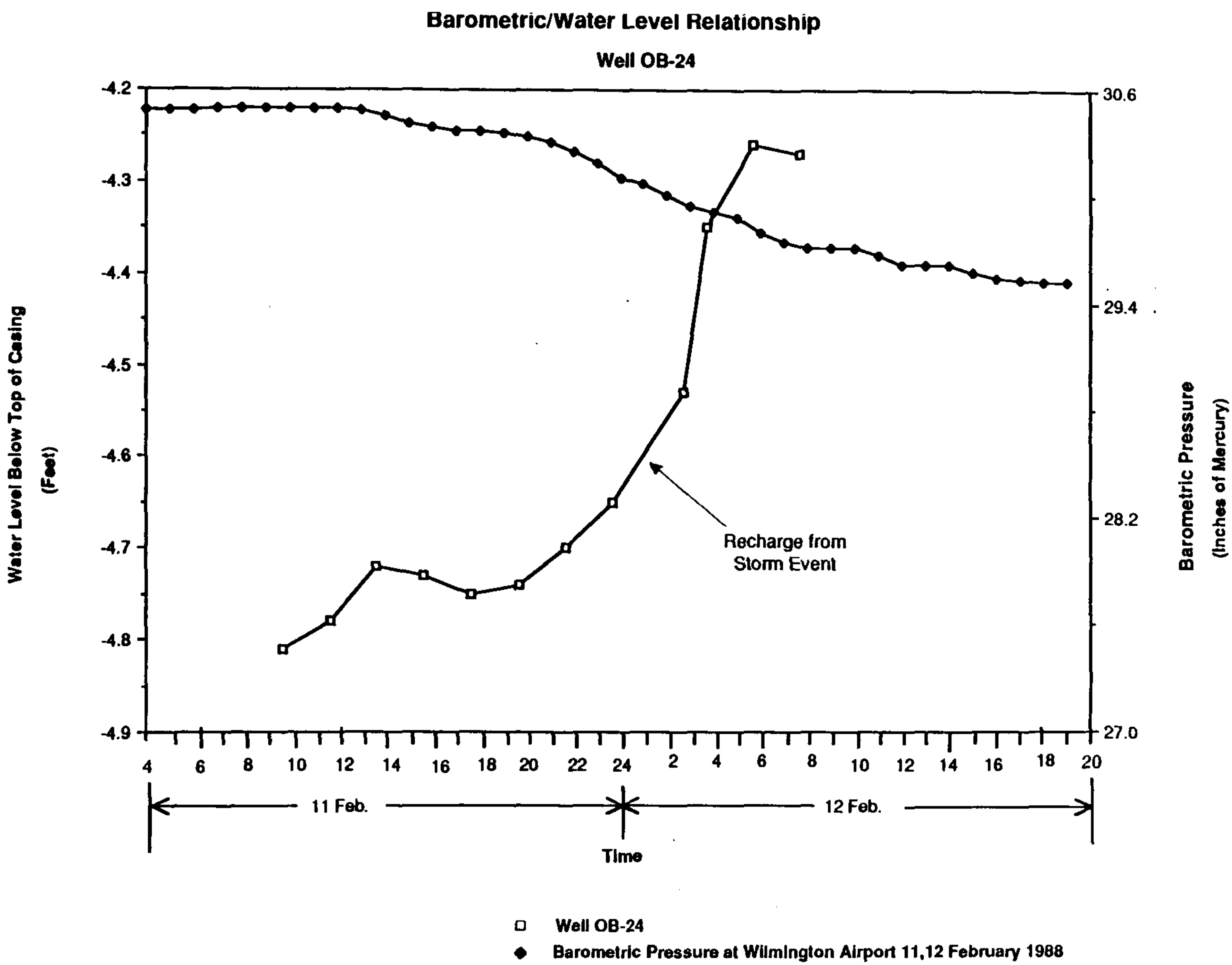
AR300875

Barometric/Water Level Relationship

Well OB-21



AR300876

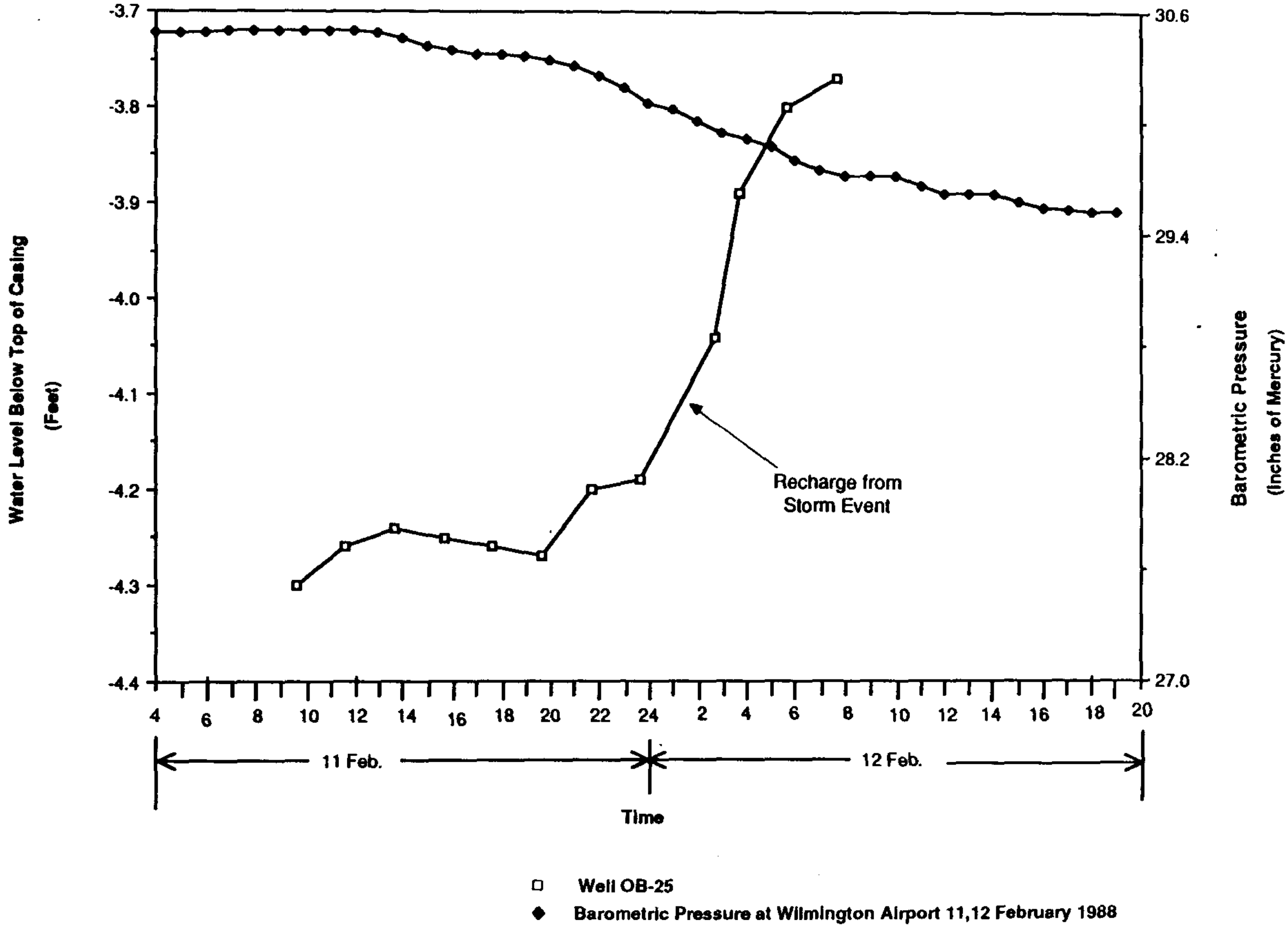


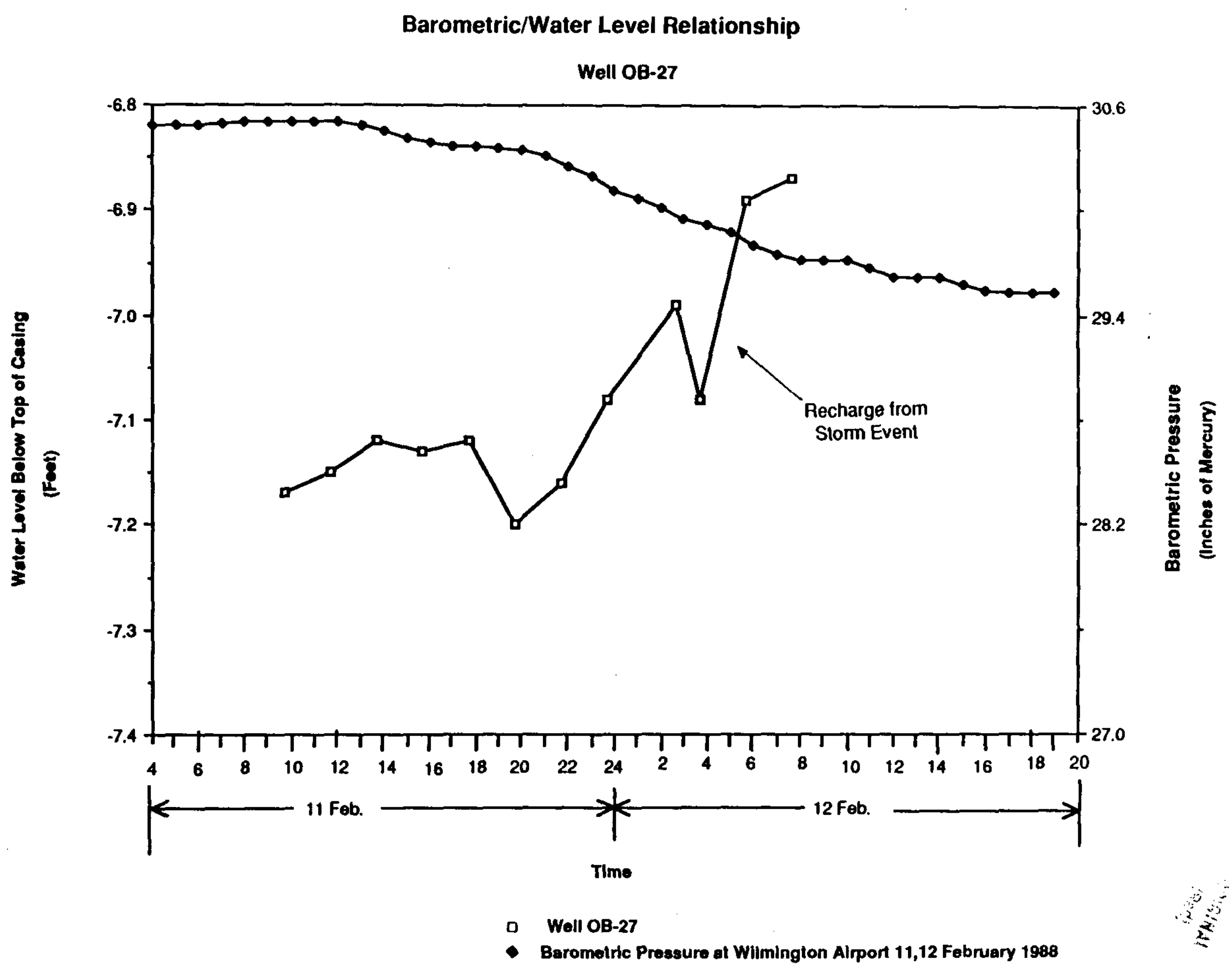
Barometric/Water Level Relationship
Well OB-24
Water Level Below Top of Casing
(Feet)
-4.2
-4.3
-4.4
-4.5
-4.6
-4.7
-4.8
-4.9
Barometric Pressure
(Inches of Mercury)
30.6
29.4
28.2
27.0
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
11 Feb.
12 Feb.
Time
Recharge from
Storm Event
Well OB-24
Barometric Pressure at Wilmington Airport 11,12 February 1988

AR300877

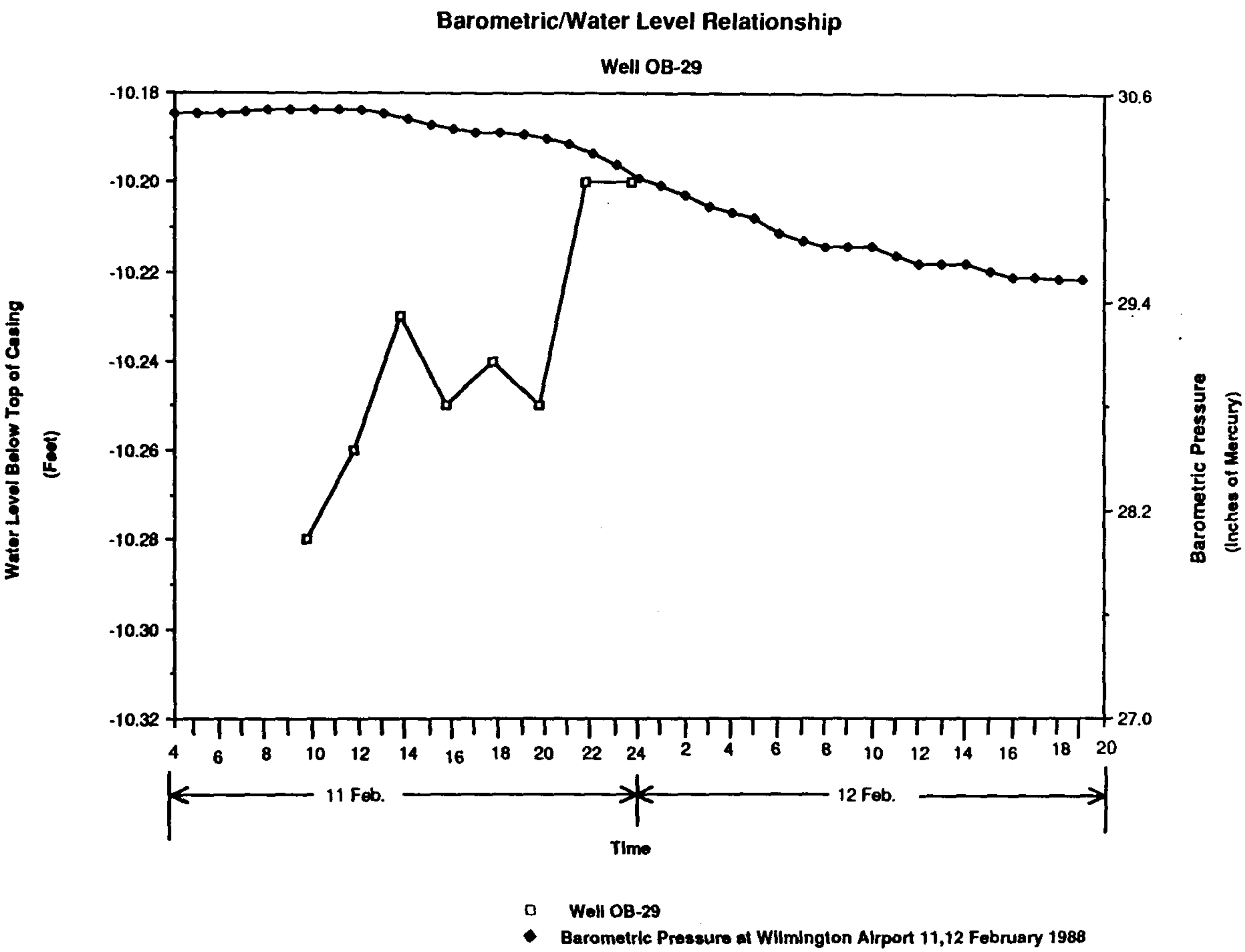
Barometric/Water Level Relationship

Well OB-25




Barometric/Water Level Relationship
Well OB-27
Water Level Below Top of Casing
(Feet)
-6.8
-6.9
-7.0
-7.1
-7.2
-7.3
-7.4
30.6
29.4
28.2
27.0
Barometric Pressure
(Inches of Mercury)
Recharge from
Storm Event
4 6 8 10 12 14 16 18 20 22 24 2 4 6 8 10 12 14 16 18 20
11 Feb.
12 Feb.
Time
Well OB-27
Barometric Pressure at Wilmington Airport 11,12 February 1988

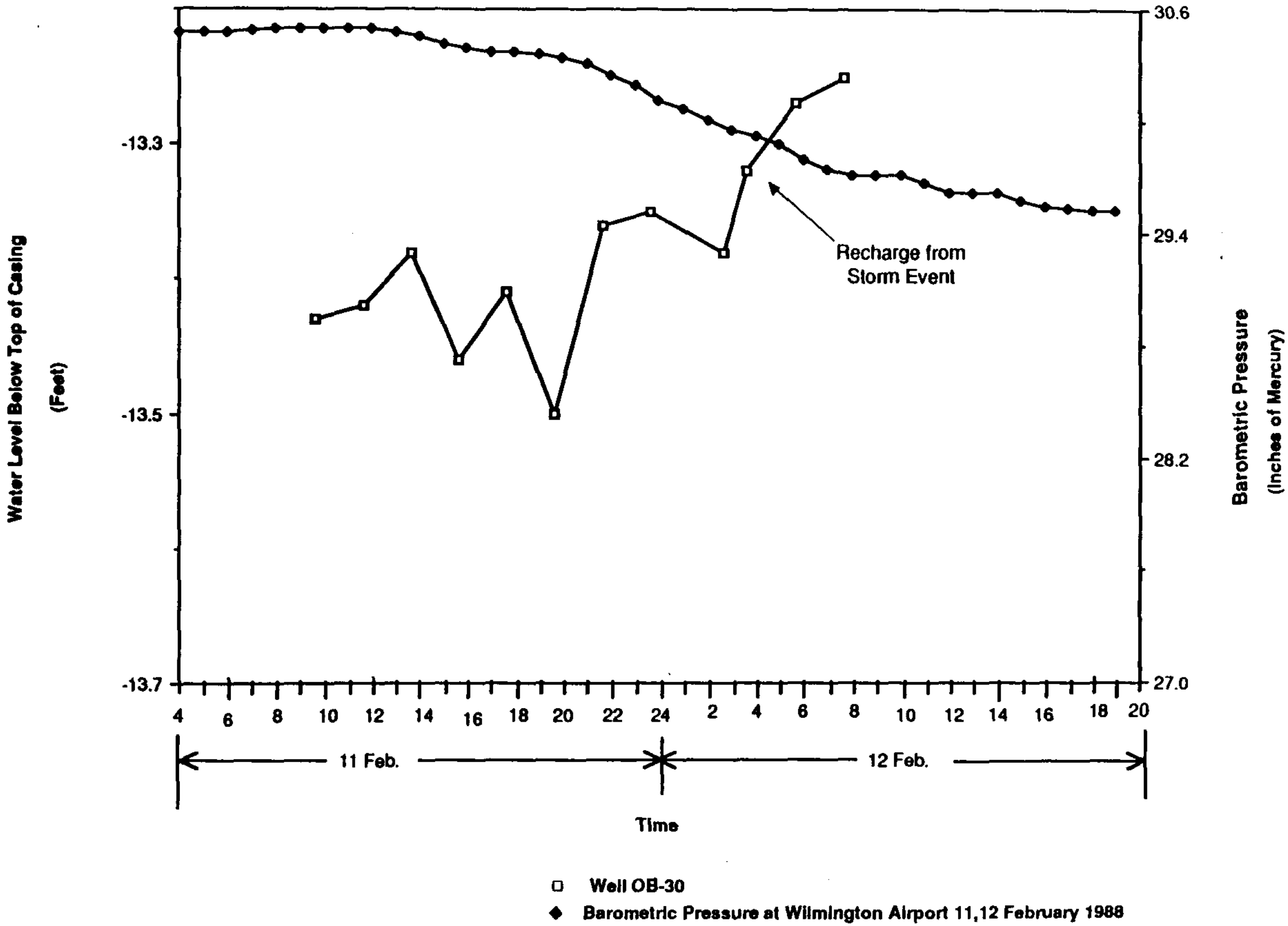
AR300879



Barometric/Water Level Relationship
Well OB-29
Water Level Below Top of Casing
(Feet)
-10.18
-10.20
-10.22
-10.24
-10.26
-10.28
-10.30
-10.32
Barometric Pressure
(Inches of Mercury)
30.6
29.4
28.2
27.0
4
6
8
10
12
14
16
18
20
22
24
2
4
6
8
10
12
14
16
18
20
11 Feb.
12 Feb.
Time
Well OB-29
Barometric Pressure at Wilmington Airport 11,12 February 1988

Barometric/Water Level Relationship

Well OB-30



AR300881

APPENDIX G

QUALITY ASSURANCE REVIEWS FOR ENVIRONMENTAL SAMPLES COLLECTED DURING THE RI

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Surface Water and Sediment Samples
Collected March 1988

July 15 1988

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 3100601

AR300883

Analytical Quality Assurance Review
New Castle Spill Site Remedial Investigation
Surface Water and Sediment Samples Collected March 1988

This analytical quality assurance review is based on the evaluation of data obtained for 6 surface water samples, 6 sediment samples, 1 set of matrix spike/matrix spike duplicate (MS/MSD) samples, 2 blind travel blanks, and laboratory method blanks collected on 14 March 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Attachment 1. The review was performed using the guidance documents entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)". A data summary table presenting the results is attached to this review.

1.0 Organic Data

1.1 Introduction

The organic analyses of the samples, associated MS/MSD samples, blind travel blanks and laboratory method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Both the surface water and sediment samples were analyzed for tris (2-chloropropyl) phosphate, which is specific to the New Castle Spill Site, according to the Contract Laboratory Program protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions) by addition of this compound to the semivolatile organic fraction library. The findings in this report are based on a review of all data deliverables required under the CLP for organic analyses. Quality assurance requirements for holding times, travel and method blank results, surrogate recoveries, DFTPP mass tuning results, MS/MSD recoveries, target compound matching quality, initial and continuing calibration data, internal standard area data and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a few qualifying statements. It is recommended that the reported results be used with the following qualifying statements. Any aspects of the data which are not discussed in this review should be considered quantitatively and qualitatively valid as reported.

1.2 Organic Qualifiers

- The detection limits for sediment samples SD-1, SD-2, SD-3 and SD-4 were raised 10 fold because matrix interferences prevented the extracts to be concentrated to the final extract volume of 1 milliliter. Extraction logs were not included with the data packages as they are not a CLP deliverable, however, laboratory personnel indicated that the extracts could only be concentrated to 10 milliliters, thus the 10 fold increase in

ATTACHMENT 1
SUMMARY OF SAMPLES FOR WHICH ANALYTICAL DATA WERE REVIEWED

Traffic Report Number	Location	Cambridge Laboratory Number
6761	WS-1	8803240-01
6762	WS-2	8803240-02
6763	WS-3	8803240-03
6764	WS-4	8803240-04
6765	WS-5	8803240-05
6766	WS-6	8803240-06
6767	Travel Blank	8803240-09
6768	SD-1	8803240-10
6769	SD-2	8803240-11
6770	SD-3	8803240-12
6771	SD-4	8803240-13
6772	SD-5	8803240-14
6773	SD-6	8803240-15
6774	Travel Blank	8803240-18

the detection limits. This should be noted when assessing the data.

- The laboratory did not report the dry weight corrected detection limits for tris (2-chloropropyl) phosphate for the sediment samples. ERM has requested that the dry weight corrected tris detection limits be submitted.

- It should be noted that the surface water samples exceeded the 40 CFR, Part 136 semivolatile water extraction holding time of 7 days by 1 day and the sediment samples by 2 days. Currently, there are no holding times specified in the Code of Federal Regulations for sediment samples, therefore ERM evaluates holding times for sediment samples to those specified for water samples in 40 CFR Part 136. The impact of exceeding the extraction holding time for such a short duration on the quantitative numbers and detection limits for the samples would be minimal, if any, because of the environmental stability of tris (2-chloropropyl) phosphate. Therefore, no action has been taken. CLP holding times from validated time of sample receipt (VTSR) were met.

2.0 Summary

The organic analyses for these samples were performed acceptably but required a qualifying statements. This analytical quality assurance review has identified the aspects of the the analytical data which have required qualifying statements. A support documentation package has been prepared for this quality assurance review and is filed with the New Castle Spill Site Remedial Investigation project file.

Report prepared by:

Lester J. Dupes
Lester J. Dupes
Quality Assurance Chemist

7/15/88
Date

David R. Blye
David R. Blye
Quality Assurance Manager

7/15/88
Date

Table 4-9
Analytical Results of Surfacewater and Sediment Samples
Newcastle Spill Site

ERM T. R. No. Sample Location Sample Date Units	6761 WS-1 3/14/88 ug/l	6762 WS-2 3/14/88 ug/l	6763 WS-3 3/14/88 ug/l	6764 WS-4 3/14/88 ug/l	6765 WS-5 3/14/88 ug/l	6766 WS-6 3/14/88 ug/l	6768 SD-1 3/14/88 ug/kg	6769 SD-2 3/14/88 ug/kg	6770 SD-3 3/14/88 ug/kg	6771 SD-4 3/14/88 ug/kg	6772 SD-5 3/14/88 ug/kg	6773 SD-6 3/14/88 ug/kg
Additional Semi Volatiles												
Tris(2-chloropropyl) Phosphate	42	35.2	26	22.4								

Qualifiers:
Blank spaces - indicate that the compound was not detected.
Sediment samples are reported on a dry weight basis.

APPROVED FOR
RELEASE BY
QUALITY ASSURANCE
David R. Blye 7/15/88
QA/QC MANAGER DATE

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Additional Samples
Collected June 1988

20 July 1988

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 3100601

Analytical Quality Assurance Review
New Castle Spill Site Remedial Investigation
Additional Samples Collected April 1988

This analytical quality assurance review is based on the evaluation of data obtained for 3 ground water samples, 1 soil sample, 1 set of matrix spike/matrix spike duplicate (MS/MSD) samples, 2 blind travel blanks, and laboratory method blanks collected on 22 June 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Attachment 1. The review was performed using the guidance documents entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)". A data summary table presenting the results is attached to this review.

1.0 Organic Data

1.1 Introduction

The organic analyses of the samples, associated MS/MSD samples, blind travel blanks and laboratory method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Samples OB-8, OB-21 (soil), and OB-21 (ground water) were analyzed for tris (2-chloropropyl)phosphate, which is specific to the New Castle Spill Site, according to the Contract Laboratory Program protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions) by addition of this compound to the semivolatile organic fraction library. Sample OB-30 was analyzed for the target compound list (TCL) volatile organic compounds and up to 10 volatile extraneous chromatographic peaks reported as tentatively identify compounds (TIC's). The findings in this report are based on a review of all data deliverables required under the CLP for organic analyses. Quality assurance requirements for holding times, travel and method blank results, surrogate recoveries, BFB and DFTPP mass tuning results, MS/MSD recoveries, target compound matching quality, initial and continuing calibration data, internal standard area data and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a qualifying statement. It is recommended that the reported results be used with the following qualifying statements. Any aspects of the data which are not discussed in this review should be considered quantitatively and qualitatively valid as reported.

1.2 Organic Qualifiers

- The presence of tris (2-chloropropyl) phosphate in soil sample OB-21 is qualitatively questionable because of the presence of similar concentration levels of this compound in both blind travel blanks. EPA protocol typically allows positive sample results that are less than or equal to five times the method or travel blank contamination levels for uncommon contaminants to be considered qualitatively questionable. The sample run sequence indicates that a blind blank was analyzed immediately before and immediately after soil sample OB-21. These blanks detected 3 J ug/l and 8 J ug/Kg of tris (2-chloropropyl) phosphate, respectively. The result for soil sample OB-21 has been flagged with a "B" to indicate it is qualitatively questionable.

2.0 Summary

The organic analyses for these samples were performed acceptably but required a qualifying statements. This analytical quality assurance review has identified the aspects of the the analytical data which have required qualifying statements. A support documentation package has been prepared for this quality assurance review and is filed with the New Castle Spill Site Remedial Investigation project file.

Report prepared by:

Lester J. Dupes
Lester J. Dupes
Quality Assurance Chemist

20 July 1988
Date

David R. Blye
David R. Blye
Quality Assurance Manager

20 July 1988
Date

ATTACHMENT 1
SUMMARY OF SAMPLES FOR WHICH ANALYTICAL DATA WERE REVIEWED

Traffic Report Number	Location	Cambridge Laboratory Number
9704	OB-30	8806278-01
9705	OB-8	8806278-02
9706	OB-21 (Ground Water)	8806278-03
9707	OB-21 (Soil)	8806278-04
9708	Blind Blank (Solid)	8806278-05
9709	Blind Blank (Water)	8806278-06

The ERM Group

Table 4 - 11
Analytical Results of Additional Samples Collected on 22 June, 1988
New Castle Spill Site

ERM T.R. # / Sample Location	Media	Analysis	Compound / Concentration
9704 / OB - 30	Ground Water	TCL Volatiles	None Detected (ug/l)
9705 / OB - 8	GroundWater	Tris (2-chloropropyl) phosphate	Tris / 3,100 (ug/l)
9706 / OB - 21	Ground Water	Tris (2-chloropropyl) phosphate	Tris / 110,000 (ug/l)
9707 / OB - 21	Soil*	Tris (2-chloropropyl) phosphate	Tris / 11 B (ug/kg)

Qualifiers:
"B"- This result is qualitatively questionable because the compound was detected in *method and/or travel blanks at similar concentrations.*
* - The soil sample value is not dry weight corrected.

APPROVED FOR RELEASE BY QUALITY ASSURANCE
David R. Blye 7/20/88
QA/QC MANAGER DATE

The ERM Group

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Ground Water Samples
Collected April 1988

29 June 1988

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 3100601

Analytical Quality Assurance Review
New Castle Spill Site Remedial Investigation
Ground Water Samples Collected April 1988

This analytical quality assurance review is based on the evaluation of data obtained for 17 ground water samples, 2 sets of matrix spike/matrix spike duplicate (MS/MSD) samples, 4 blind travel blanks, and laboratory method blanks collected from 18 April to 21 April 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Attachment 1. The review was performed using the guidance documents entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)". A data summary table presenting the results is attached to this review.

1.0 Organic Data

1.1 Introduction

The organic analyses of the 17 ground water samples, associated MS/MSD samples, blind travel blanks and laboratory method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for the target compound list (TCL) volatile and semivolatile organic compounds according to the Contract Laboratory Program protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions). An additional compound, tris(2-chloropropyl)phosphate, which is specific to the New Castle Spill Site was analyzed for in the samples by addition of this compound to the semivolatile organic fraction library. Mass spectral library searches were performed for up to 20 semivolatile and up to 10 volatile extraneous chromatographic peaks and reported as tentatively identify compounds (TIC's). The classical water chemistry parameters COD and TOC were also analyzed for according to methods 410.1 and 415.1 respectively, as referenced in "Methods for Chemical Analysis of Water and Wastes" (EPA-600/4-79-020 March 1983). The findings in this report are based on a review of all data deliverables required under the CLP for organic analyses. Quality assurance requirements for holding times, travel and method blank results, surrogate recoveries, BFB and DFTPP mass tuning results, MS/MSD recoveries, target compound matching quality, initial and continuing calibration data, internal standard area data and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a few qualifying statements. It is recommended that the reported results be used with the following qualifying statements. Any aspects of the data which are not discussed in this review should be considered quantitatively and qualitatively valid as reported.

1.2 Volatile Organic Qualifiers

- The presence of methylene chloride, acetone and toluene in the samples listed below is qualitatively questionable because of the presence of these compounds in associated travel and/or laboratory method blanks. EPA protocol allows positive sample results that are less than or equal to 10 times the travel or method blank contamination levels of common laboratory contaminants such as these compounds to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the attached data summary table.

Compound	Samples with Questionable Results
methylene chloride	All samples with positive results
acetone	All samples with positive results
toluene	Sample OB-21

- The presence of 2-butanone, 4-methyl-2-pentanone, 2-hexanone and tetrachloroethene in the groundwater sample OB-28 and tetrachloroethene in OB-3 is qualitatively questionable because of the presence of these compounds in travel and/or laboratory method blanks. EPA protocol allows positive sample results that are less than or equal to 5 times the travel or method blank contamination levels of contaminants such as these compounds to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the attached data summary table.

- The reported detection limits for 2-hexanone for ground water samples OB-11, MW-77 (Blind Travel Blank), OB-25, OB-10, OB-24, MW-2 MS and MW-2 MSD should be considered quantitative estimates because the percent difference (%D) between the initial calibration average response factor and the continuing calibration response factor (81.8%) exceeded 50%. No positive results were reported for this compound in any of the above samples. This high %D indicates a lack of instrument stability for this compound.

- The reported detection limits for 2-hexanone for ground water samples OB-11, OB-2, and MW-1 should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor (93.6%) exceeded 50%. No positive results were reported for this compound in any of the above samples. This high %D indicates a lack of instrument stability for this compound.

- The reported detection limits for chloromethane, acetone, 2-butanone, vinyl acetate, 4-methyl-2-petanone, and 2-hexanone for ground water samples OB-27, MW-2, MW-78 (blind travel blank), OB-8, OB-21 and OB-16 should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for these compounds in any of the above samples with the exception of acetone in OB-21. However, this acetone was previously qualified as being qualitatively questionable (see above) in this sample. These elevated %Ds indicate a lack of instrument stability for these compounds.

- As required by CLP protocols, all TIC's found in the volatile fraction have been flagged with a "J" to indicate they are estimated quantitative values. ERM has reported on the data summary tables only those TIC's which were demonstrated not to be the result of laboratory contamination or instrument artifacts.

- As required by CLP protocols, all compounds which were qualitatively identified at a concentration below the CLP contract required detection limit have been flagged with a "J" to indicate they are quantitative estimates.

1.3 Semivolatile Organic Qualifiers

- The presence of diethyl phthalate and bis(2-ethylhexyl) phthalate in all ground water samples with positive results is qualitatively questionable because of the presence of these compounds in travel and/or laboratory method blanks. EPA protocol allows sample results that are less than or equal to 10 times the travel or method blank contamination levels of common laboratory contaminants such as phthalate esters to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results.

- The presence of tris(2-chloropropyl)phosphate in ground water samples MW-5, OB-28 and MW-2 is qualitatively questionable because of the presence of this compound in an associated travel and/or laboratory method blank. EPA protocol allows sample results that are less than or equal to 5 times the travel or method blank contamination levels of uncommon contaminants to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results.

- The detection limits for the semivolatile acid extractable compounds in ground water samples, MW-4, MW-3, MW-5, OB-2 and MW-1 may be higher than reported because two or more acid surrogates were outside the quality control limits. Reextraction and reanalysis of the samples resulted in similar acid surrogate spike recoveries, confirming the presence of a matrix interference problem with the samples. Data has been reported on the data summary from the reextraction analyses if the compound was not present in the original analysis. It should also be noted that the reextractions were performed past the 40 CFR Part 136, 7 day extraction holding time. The initial extractions were within the allowable holding time.

- The reported detection limits for isophorone and benzoic acid for ground water samples MW-2, OB-8, OB-21, MW-4, MW-3 and MW-5, and for benzoic acid and 2,4 dinitrophenol in ground water sample OB-24 should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for these compounds in any of the above samples. These high %Ds indicate a lack of instrument stability for these compounds.

- It should be noted that the tris (2-chloropropyl) phosphate ("tris") standards had three distinct peaks eluting closely together in sequence at an approximate retention time of 21 minutes. The mass spectrum of each of these peaks were identical, indicating the apparent presence of three individual tris isomers or three groups of tris isomers which co-elute. The first peak consistently had the highest response factor of approximately 0.3 (using d10-phenanthrene as the internal standard) with the next two peaks decreasing to about 0.15 and 0.03, respectively. The ground water samples which had tris present also showed the distinct three peak chromatography pattern. Therefore, quantitation for tris in the ground water samples was done using the first tris peak because it had the highest response factor. Quantitation using the other two peaks showed concentrations which were very similar. Quantitation using the total area of the three peaks and a single response factor calculated from the total area of the three peaks in the standard also showed little difference in the calculated concentration. A separate quantitation routine from the remainder of the semivolatile target compounds was created to quantitate tris.

  Additionally, during review of the semivolatile TICs for the samples where tris was reported as being detected, it was found that tris was also searched and reported as a TIC. This was found by comparing the retention times and mass spectrum for the TICs to those identified as tris. Therefore, since positive qualitative identification and quantitation to tris standards had been performed, those compounds which were identified as tris during library searching were removed from the TIC list for these samples.

- As required by CLP protocols, all TICs found in the semivolatile fraction have been flagged with a "J" to indicate they are estimated quantitative values. ERM has reported on the data summary tables only those TICs which were demonstrated not to be the result of laboratory contamination or instrument artifacts.

- As required by CLP protocol, all compounds which were qualitatively identified at a concentration below the CLP contract required detection limits have been flagged with a "J" to indicate they are quantitative estimates.

2.0 Inorganic Data

2.1 Introduction

The inorganic analyses of the 17 ground water samples, associated MS and laboratory duplicate samples, and blind travel and method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for 2 elements, iron and manganese, according to the Contract Laboratory Program protocols specified in the Statement of Work for Inorganic Analyses (SOW 7/85). The samples were analyzed using Inductively Coupled Plasma emission (ICP) spectrometry. The findings in this report are based on a review of all data required under the CLP for inorganic analyses. Quality assurance requirements for holding times, travel and method blank results, matrix spikes, laboratory duplicates, detection limits, initial and continuing calibrations, interference checks, serial dilution analyses and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a few qualifying statements. It is recommended that the reported results be used with the following qualifier statements.

2.2 Inorganic Qualifiers

- The presence of iron in the ground water samples OB-27, OB-25, OB-10, MW-2, OB-11, OB-21, OB-16, OB-2 and OB-28 is considered qualitatively questionable because of the presence of iron in travel and/or laboratory blanks. EPA protocol allows sample results that are less than or equal to 10 times the travel blank, the laboratory preparation blank and/or the calibration blank concentrations of elemental contamination to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the data summary table.

- The positive result for iron in ground water sample OB-3 should be considered estimated because of a low iron matrix spike recovery for this sample. It should be noted, however, that the sample concentration exceeded the spike concentration by a factor of approximately 19 fold. A "J" has been placed next to the sample result on the data summary table.

- The iron and manganese ground water concentrations have been flagged with an "E" qualifier as required by CLP protocol because the associated ICP serial dilution quality control analyses exceeded the allowable 10% difference acceptance criteria. The CLP ICP protocols require that a serial dilution analysis must be performed on each group of samples with a similar matrix type and concentration, for each case of samples, for each 20 samples received, or for samples received over a 14 calendar day period, whichever is more frequent. The ICP serial dilution analysis requires a 5-fold dilution of the selected sample to agree within 10% of the original analysis. If the analyses exceed the 10% difference criteria, a physical or chemical interference effect can be suspected. CLP protocol requires that all of the data of samples associated with that serial dilution must be flagged with an "E".

Ground water samples from wells MW-2 and OB-3 exceeded the 10% difference criteria for their respective iron and manganese serial dilution analyses. Therefore, the remainder of the sample results were flagged with an "E". However, it is ERM's opinion that physical and chemical interference are highly sample matrix dependent and that interference judgements on samples other than those actually run for serial dilution analysis can not be inferred. ERM has reported the remaining results not already qualified with a B or J with the "E" qualifier as required by CLP protocol, but feels these data can be used confidently.

2.0 Summary

The organic and inorganic analyses for these ground water samples were performed acceptably but required a few qualifying statements. This analytical quality assurance review has identified the aspects of the the analytical data which have required qualifying statements. A support documentation package has been prepared for this quality assurance review and is filed with the New Castle Spill Site Remedial Investigation project file.

Report prepared by:

Lester J. Dupes (signature)
Lester J. Dupes
Quality Assurance Chemist

29 June 1988
Date

David R. Blye (signature)
David R. Blye
Quality Assurance Manager

29 June 1988
Date

The ERM Group

ATTACHMENT 1
SUMMARY OF SAMPLES FOR WHICH ANALYTICAL DATA WERE REVIEWED

Traffic Report Number	Location	Cambridge Laboratory Number
7797	Blind Blank	8804185-01
7798	MW-4	8804185-02
7799	MW-3	8804185-03
7800	MW-5	8804185-04
7801	Blind Blank	8804197-01
7802	OB-28	8804197-02
7803	OB-1	8804197-03
7804	OB-2	8804197-04
7805	MW-1	8804197-05
7806	OB-3	8804197-06
7813	OB-11	8804216-01
7807	Blind Blank	8804216-02
7808	OB-27	8804216-03
7809	OB-25	8804216-04
7810	OB-10	8804216-05
7811	OB-24	8804216-06
7812	MW-2	8804216-07
7814	Blind Blank	8804235-01
7815	OB-8	8804235-02
7816	OB-21	8804235-03
7817	OB-16	8804235-04

Table 4-5
Analytical Results For Ground Water Samples
New Castle Spill Site

File: 310.06.01

ERM T. R. No. Sample Location Sample Date Units	7798 MW-4 4/18/88 ug/l	7799 MW-3 4/18/88 ug/l	7800 MW-5 4/18/88 ug/l	7802 OB-28 4/19/88 ug/l	7803 OB-1 4/19/88 ug/l	7804 OB-2 4/19/88 ug/l	7805 MW-1 4/19/88 ug/l	7806 OB-3 4/19/88 ug/l
Volatile Organics								
Methylene Chloride				3 B	2 B	2 B	2 B	4 B
Acetone				6 B			1 B	1 B
Carbon Disulfide				15				
1,2-Dichloroethene (total)		5			11			
2-Butanone				2 B				
Trichloroethene		93	66		120		23	1 J
4-Methyl-2-Pentanone				2 B				
2-Hexanone				2 B				
Tetrachloroethene				2 B				1 B
Tentatively Indentified Volatile Compounds								
Trichlorofluoromethane			18 J					
Unkown	5 J							
Semi Volatiles								
1,2-Dichlorobenzene	2 J							
Diethylphthalate	8 B*	6 B*	4 B*					
Bis(2-Ethylhexyl)Phthalate	4 B*	12 B*	8 B*	7 B	3 B	4 B		3 B
Tentatively Indentified Semi Volatile Compounds								
hexadecanoic acid								10 J
2-Butoxy-Ethanol	440 J							
total unknowns	2276 J	24 J	114 J*		16 J	44 J		
Additional Semi Volatiles								
Tris(2-chloropropyl) Phosphate	17.1 *		2.4 B*	6.14 B				
Inorganics								
Iron	843 E	15900 E	719 E	432 B	18800 E	293 B	3900 E	19400 J
Manganese	5230 E	4820 E	1060 E	62 E	635 E	5240 E	2100 E	1060 E
COD	19000	6000	68000	12000	42000	25000	9700	32000
TOC	1500	940	1300	2500	4400	3200	1400	6600

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"E" - The associated ICP serial dilution analysis exceeded the allowable 10% difference from the undiluted analysis.
"*" - This result is from a reextraction analysis.

APPROVED FOR
RELEASE BY
QUALITY ASSURANCE
David R Blye 7/11/88
DATE

Table 4-5
Analytical Results For Ground Water Samples
New Castle Spill Site

File: 310.06.01

ERM T. R. No. Sample Location Sample Date Units	7808 OB-27 4/20/88 ug/l	7809 OB-25 4/20/88 ug/l	7810 OB-10 4/20/88 ug/l	7811 OB-24 4/20/88 ug/l	7812 MW-2 4/20/88 ug/l	7813 OB-11 4/20/88 ug/l	7815 OB-8 4/21/88 ug/l	7816 OB-21 4/21/88 ug/l	7817 OB-16 4/21/88 ug/l
Volatile Organics									
Methylene Chloride		2 B				8 B		41 B	
Acetone			3 B			5 B		15 B	
Trichloroethene					8			2 J	
Toluene								3 B	
Tentatively Indentified Volatile Compounds									
Dichlorofluoromethane							29 J	3 J	
Trichlorofluoromethane							950 J	50 J	13 J
total unknowns							17 J		
Semi Volatiles									
naphthalene							8 J	8 J	
2-methylnaphthalene							5 J		
fluorene							2 J		
Diethylphthalate					5 B		4 B	6 B	4 B
bis(chloroisopropyl)ether								6 J	
Bis(2-Ethylhexyl)Phthalate	9 B	17 B	15 B	20 B	19 B	3 B	7 B	7 B	6 B
Tentatively Indentified Semivolatile Compounds									
5-methyl-2-hexanone				14 J					
total dimethyl napthalene isomers							24 J		
total unknowns	10 J	26 J	28 J	84 J	40 J		198 J	474 J	48 J
Additional Semi Volatiles									
Tris(2-chloropropyl) Phosphate		66.6	179	188	12.6 B		2160 **	74600 **	51.4
Inorganics									
Iron	34 B	27 B	39 B	13000 E	357 B	39 B	4600 E	111 B	100 B
Manganese			65 E	1150 E	456 E	81 E	1630 E	1780 E	26 E
COD	9700	110000	21000	14000	6000	31000	60000	280000	87000
TOC	1300	3100	4600	3500	1300	3600	15000	130000	2200

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"E" - The associated ICP serial dilution analysis exceeded the allowable 10% difference from the undiluted analysis.
"*" - This result is from a reextraction analysis.
"**" - Value reported from dilution analysis to allow accurate quantitation.

APPROVED FOR
RELEASE BY
QUALITY ASSURANCE
David R. Blye 7/11/88
QA/QC MANAGER DATE

AR300902

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Soil Samples
Collected March 1988

July 15 1988

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 3100601

The ERM Group

Analytical Quality Assurance Review
New Castle Spill Site Remedial Investigation
Soil Samples Collected March 1988

This analytical quality assurance review is based on the evaluation of data obtained for 15 soil samples, associated matrix spike/matrix spike duplicate (MS/MSD) samples, 6 blind travel blanks, and laboratory method blanks collected from 7 March to 18 March 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Attachment 1. The review was performed using the guidance document entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)". A data summary table presenting the results is attached to this review.

1.0 Organic Data

1.1 Introduction

The organic analyses of the 15 soil samples, associated MS/MSD samples, blind travel blanks and laboratory method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for the target compound list (TCL) volatile and semivolatile organic compounds according to the Contract Laboratory Program protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions). An additional compound, tris(2-chloropropyl)phosphate, which is specific to the New Castle Spill Site was analyzed for in the samples by addition of this compound to the semivolatile organic fraction library. Mass spectral library searches were performed for up to 20 semivolatile and up to 10 volatile extraneous chromatographic peaks and reported as tentatively identify compounds (TIC's). The findings in this report are based on a review of all data deliverables required under the CLP for organic analyses. Quality assurance requirements for holding times, travel and method blank results, surrogate recoveries, BFB and DFTPP mass tuning results, MS/MSD recoveries, target compound matching quality, initial and continuing calibration data, internal standard area data and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a few qualifying statements. It is recommended that the reported results be used with the following qualifying statements. Any aspects of the data which are not discussed in this review should be considered quantitatively and qualitatively valid as reported.

1.2 Volatile Organic Qualifiers

- The presence of methylene chloride, acetone and toluene in the samples listed below is qualitatively questionable because of the presence of these compounds in associated travel and/or laboratory method blanks. EPA protocol allows positive sample results that are less than or equal to 10 times the travel or method blank contamination levels of common laboratory contaminants such as these compounds to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the attached data summary table.

Compound	Samples with Questionable Results
methylene chloride	All samples with positive results
acetone	All samples with positive results
toluene	Sample MW-5 (4-6')

- The presence of 2-butanone in soil samples PW-1 (2-4') and B-2 (2-4') and total xylenes in sample B-2 (2-4') is qualitatively questionable because of the presence of these compounds in travel and/or laboratory method blanks. EPA protocol allows positive sample results that are less than or equal to 5 times the travel or method blank contamination levels of contaminants such as these compounds to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the attached data summary table.

- The actual detection limits for all volatile compounds in sample MW-2 (2-4') are probably slightly higher than reported by the laboratory because the sample was analyzed two days past the recommended 10 day volatile analysis holding time for soils. Currently, there are no analysis holding times for soil samples specified in the Code of Federal Regulations. ERM typically evaluates soil analysis holding times according to those specified for water samples in 40 CFR Part 136. The 40 CFR Part 146 water holding times specify a 7 day holding time for aromatic volatile compounds and a 14 day holding time for halogenated volatile compounds. The holding time for water samples being analyzed for aromatic volatile compounds can be increased to 14 days if the samples are preserved with hydrochloric acid. The only method of preservation for soil samples is refrigeration to a temperature of 4 degrees celcius. Therefore, ERM evaluates holding times for the volatile analysis of soil samples using the CLP holding time of 10 days. However, ERM specifies the analysis must be completed within 10 days from the date the sample was collected not from the date the sample was received at the laboratory. The 2 day duration the holding time was exceeded for this sample would have minimal impact on the sample results. The only volatile compound which was detected in the sample was methylene chloride at a concentration that was attributable to laboratory contamination.

- The reported detection limits for chloromethane, and total xylenes for soil samples PW-1 (2-4'), B-3 (0-2') and B-2 (2-4') should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for these compounds in any of the above samples with the exception of total xylene in B-2 (2-4'). However, total xylene was previously qualified as being qualitatively questionable (see above) in this sample. These elevated %Ds indicate a lack of instrument stability for these compounds.

- The reported detection limits for total xylenes for soil samples MW-1 (0-2'), MW-1 (2-4'), MW-3 (4-6'), and MW-4 (2-4') should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for this compound in any of the above samples. This elevated %D indicates a lack of instrument stability for this compound.

- As required by CLP protocols, all TIC's found in the volatile fraction have been flagged with a "J" to indicate they are estimated quantitative values. ERM has reported on the data summary tables only those TIC's which were demonstrated not to be the result of laboratory contamination or instrument artifacts.

- As required by CLP protocols, all compounds which were qualitatively identified at a concentration below the CLP contract required detection limit have been flagged with a "J" to indicate they are quantitative estimates.

1.3 Semivolatile Organic Qualifiers

- The presence of diethyl phthalate, di-n-butyl phthalate and bis(2-ethylhexyl) phthalate in the soil samples listed below is qualitatively questionable because of the presence of these compounds in travel and/or laboratory method blanks. EPA protocol allows sample results that are less than or equal to 10 times the travel or method blank contamination levels of common laboratory contaminants such as phthalate esters to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results.

Compound	Samples with Questionable Results
diethyl phthalate	All samples with positive results
di-n-butyl phthalate	All samples with positive results
bis (2-ethylhexyl) phthalate	Sample MW-5 (4-6')

- The reported detection limits for benzoic acid for soil samples MW-5 (2-4'), MW-5 (4-6'), MW-5 (6-8'), PW-1 (0-2'), PW-1 (2-4'), B-3 (0-2'), B-2 (2-4') and B-2 (4-6.5') should be considered quantitative estimates because the %D between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for this compound in any of the above samples. This high %D indicates a lack of instrument stability for this compound.

- The semivolatile detection limits and positive results for soil samples B-1 (6-8'), MW-1 (0-2'), MW-1 (2-4'), MW-2 (2-4'), MW-5 (2-4'), MW-5 (4-6'), MW-5 (6-8'), PW-1 (0-2'), and PW-1 (2-4') are probably slightly higher than reported by the laboratory because the 40 CFR Part 136, 7 day water extraction holding time was exceeded by 1 to 2 days for these samples. It should be noted that there are currently no analysis holding times specified for soil samples in the Code of Federal Regulations. Therefore, ERM evaluates soil analysis holding times to those specified for water samples. The short duration the extraction holding time was exceeded would have a minimal impact on the semivolatile results for these samples, particularly in light of the chemical stability of these compounds. However, the positive semivolatile results for the above samples have been flagged with a "J" to indicate they may be quantitative estimates because of exceeding the extraction holding time.

- It should be noted that the tris (2-chloropropyl) phosphate ("tris") standards had three distinct peaks eluting closely together in sequence at an approximate retention time of 20 minutes. The mass spectrum of each of these peaks were identical, indicating the apparent presence of three individual tris isomers or three groups of tris isomers which co-elute. The first peak consistently had the highest response factor of approximately 0.3 (using d10-phenanthrene as the internal standard) with the next two peaks decreasing to about 0.15 and 0.03, respectively. The soil samples which had tris present also showed the distinct three peak chromatography pattern. Therefore, quantitation for tris in the soil samples was done using the first tris peak because it had the highest response factor. Quantitation using the other two peaks showed concentrations which were very similar. Quantitation using the total area of the three peaks and a single response factor calculated from the total area of the three peaks in the standard also showed little difference in the calculated concentration. A separate quantitation routine from the remainder of the semivolatile target compounds was created to quantitate tris.

- The laboratory did not report the results for tris on a dry weight basis. The laboratory was contacted and has resubmitted the tris values on a dry weight basis.

- As required by CLP protocols, all TICs found in the semivolatile fraction have been flagged with a "J" to indicate they are estimated quantitative values. ERM has reported on the data summary tables only those TICs which were demonstrated not to be the result of laboratory contamination or instrument artifacts.

- As required by CLP protocol, all compounds which were qualitatively identified at a concentration below the CLP contract required detection limits have been flagged with a "J" to indicate they are quantitative estimates.

2.0 Summary

The organic analyses for these soil samples were performed acceptably but required a few qualifying statements. This analytical quality assurance review has identified the aspects of the the analytical data which have required qualifying statements. A support documentation package has been prepared for this quality assurance review and is filed with the New Castle Spill Site Remedial Investigation project file.

Report prepared by:

Lester J. Dupes
Lester J. Dupes
Quality Assurance Chemist

15 July 1988
Date

David R Blye
David R. Blye
Quality Assurance Manager

15 July 1988
Date

AR300908

The ERM Group

ATTACHMENT 1
SUMMARY OF SAMPLES FOR WHICH ANALYTICAL DATA WERE REVIEWED

Traffic Report Number	Location	Cambridge Laboratory Number
6605	B-1 (6-8')	8803112-01
6606	Blind Blank	8803112-02
6607	MW-1 (0-2')	8803113-02
6608	MW-1 (2-4')	8803113-02
6609	Blind Blank	8803113-03
6610	MW-2 (2-4')	8803169-01
6611	MW-3 (4-6')	8803169-04
6612	MW-4 (6-8')	8803169-05
6613	Blind Blank	8803169-06
6614	MW-4 (2-4')	8803169-07
6615	MW-5 (2-4')	8803205-01
6616	MW-5 (4-6')	8803205-02
6617	MW-5 (6-8')	8803205-03
6618	Blind Blank	8803205-04
6619	PW-1 (0-2')	8803255-01
6620	PW-1 (2-4')	8803255-02
6621	Blind Blank	8803255-03
6867	B-3 (0-2')	8803273-02
6869	B-2 (2-4')	8803273-03
6870	B-2 (4-6.5')	8803273-04
6866	Travel Blank	8803273-01

Table 4-7
Analytical Results For Soil Samples
New Castle Spill Site
All results are reported in units of ug/kg on a dry weight basis

File: 310.06.01

ERM T. R. No. Sample Location Sample Date Units	6605 B-1,(6-8') 3/7/88 ug/kg	6607 MW-1(0-2') 3/8/88 ug/kg	6608 MW-1(2-4') 3/8/88 ug/kg	6610 MW-2(2-4') 3/9/88 ug/kg	6611 MW-3(4-6') 3/10/88 ug/kg	6612 MW-4(6-8') 3/11/88 ug/kg	6614 MW-4(2-4') 3/11/88 ug/kg
Volatile Organics							
Methylene Chloride	9 B	11 B	15 B	7 B	14 B	14 B	11 B
Tentatively Indentified Volatile Compounds							
Semi Volatiles							
Diethylphthalate				92 B	50 B	54 B	39 B
Phenanthrene		58 J		400 J			
Fluoranthene		220 J		570 J			
Anthracene				78 J			
Pyrene		130 J		190 J			
Benzo(a) Anthracene		83 J		140 J			
Chrysene		130 J		140 J			
Bis(2-Ethylhexyl)Phthalate		51 B	40 B			38 J	
Benzo(b) Fluoranthene (1)		200 J		230 J			
Benzo(a) Pyrene		94 J		91 J			
Indeno(1,2,3-cd) Pyrene		100 J					
Tentatively Indentified Semivolatile Compounds							
5-Ethyl-2-Methyl-Octane							
Octadecanal		1400 J	340 J				
1,3,5 -Cycloheptatriene							
Unknown Alkyl Benzene							
Unknown Acid		400 J					
Total Unknown Alkane		1560 J					
Total Unknowns		2840 J		950 J	2200 J	1600 J	
Additional Semi Volatiles							
Tris(2-chloropropyl) Phosphate				336 J			
Acidity-EPA 305.1 (ug/g as CaCO3)	60	480	<24	<25	98	47	87
Specific Gravity (g/ml)	2.62	2.72	2.78	2.65	2.6	2.65	2.8

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations
"J" - This result is an estimated concentration.
Blank spaces - indicate the compound was not detected.
(1) - Benzo(b)fluoranthene and Benzo(k)fluoranthene are not resolved by the analytical method. The concentration represents the total of both isomers.

ORIGINAL (Red)
APPROVED FOR RELEASE BY QUALITY ASSURANCE
David R. Blye 7/15/88
QA/QC MANAGER DATE

Table 4-7
Analytical Results For Soil Samples
New Castle Spill Site
All results are reported in units of ug/kg on a dry weight basis

File: 310 06 01

ERM T. R. No. Sample Location Sample Date Units	6615 MW-5(2-4') 3/14/88 ug/kg	6616 MW-5(4-6') 3/14/88 ug/kg	6617 MW-5(6-8') 3/14/88 ug/kg	6619 PW-1(0-2') 3/16/88 ug/kg	6620 PW-1(2-4') 3/16/88 ug/kg	6867 B-3(0-2') 3/18/88 ug/kg	6869 B-2(2-4') 3/18/88 ug/kg	6870 B-2(4-6.5') 3/18/88 ug/kg
Volatile Organics								
Methylene Chloride	78 B	8 B	6 B	20 B	13 B	16 B	12 B	6 B
Acetone	200 B	59 B			11 B	18 B	110 B	51 B
Carbon Disulfide	6 J							
2-Butanone					2 B		11 B	47
Toluene		2 B						
Ethylbenzene							11	
Total Xylenes							25 B	
Tentatively Indentified Volatile Compounds								
Trichlorofluoromethane	180 J	670 J						
Acetaldehyde							72 J	42 J
Trimethyl-Silanol							16 J	
Total Unknowns	83 J	24 J						
Semi Volatiles								
Naphthalene	390 J							
Acenaphthene	580 J							
Isophorone							79 J	
2-Methyl Naphthalene				42 J				
Dibenzofuran	470 J							
Fluorene	580 J							
Phenanthrene	4400 J	140 J	110 J	95 J				
Di-n-Butylphthalate				410 B	77 B			
Fluoranthene	3600 J	180 J	130 J	140 J	53 J			
Anthracene	1100 J							
Pyrene	2400 J	150 J	98 J	110 J	39 J	44 J		
Benzo(a) Anthracene	1300 J	68 J	41 J	61 J				
Chrysene	1800 J	74 J	55 J	140 J	47 J			
Bis(2-Ethylhexyl)Phthalate				190 B	44 B			
Benzo(b) Fluoranthene (1)	2500 J	110 J		190 J	87 J			
Benzo(a) Pyrene	1200 J							
Tentatively Indentified Semivolatile Compounds								
5-Ethyl-2-Methyl-Octane				480 J				
Unknown Alkyl Benzene							550 J	
Total Unknowns		1370 J	300 J		8000 J		3550 J	3530 J
Additional Semi Volatiles								
Tris(2-chloropropyl) Phosphate	11800 J	4060 J	1970 J	2640 J	3780 J	504	53.9 J	54.7 J
Acidity-EPA 305.1 (ug/g as CaCO3)	<22	<22	<22	580	340	440	240	141
Specific Gravity (g/ml)	2.51	2.67	2.6	1.77	2.69	2.51	2.58	2.63

Qualifiers:
"B" - This result is qualitatively questionable becasue the compound was detected in method and/or travel blanks at similar concentrations
"J" - This result is an estimated concentration.
Blank spaces - indicate the compound was not detected.
(1) - Benzo(b)fluoranthene and Benzo(k)fluoranthene are not resolved by the analytical method. The concentration represents the total of both isomers.

ORIGINAL (Red)

APPROVED FOR RELEASE BY QUALITY ASSURANCE
David R. Blye 7/15/88
QA/QC MANAGER DATE

ORIGINAL (Red)

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Production Well Samples
Collected May 1988

15 July 1988

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 3100601

The ERM Group

Analytical Quality Assurance Review
New Castle Spill Site Remedial Investigation
Production Well Samples Collected May 1988

This analytical quality assurance review is based on the evaluation of data obtained for 2 production well samples, matrix spike/matrix spike duplicate (MS/MSD) samples, a blind travel blank, and laboratory method blanks collected from 12 May to 13 May 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Attachment 1. The review was performed using the guidance documents entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)". A data summary table presenting the results is attached to this review.

1.0 Organic Data

1.1 Introduction

The organic analyses of the 2 production well samples, associated MS/MSD samples, blind travel blank and laboratory method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for the target compound list (TCL) volatile and semivolatile organic compounds according to the Contract Laboratory Program protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions). An additional compound, tris(2-chloropropyl)phosphate, which is specific to the New Castle Spill Site was analyzed for in the samples by addition of this compound to the semivolatile organic fraction library. Mass spectral library searches were performed for up to 20 semivolatile and up to 10 volatile extraneous chromatographic peaks and reported as tentatively identify compounds (TIC's). The classical water chemistry parameters COD, TOC, and total phenols were also analyzed for according to methods 410.1, 415.1 and 420.2 respectively, as referenced in "Methods for Chemical Analysis of Water and Wastes" (EPA-600/4-79-020 March 1983). The findings in this report are based on a review of all data deliverables required under the CLP for organic analyses. Quality assurance requirements for holding times, travel and method blank results, surrogate recoveries, BFB and DFTPP mass tuning results, MS/MSD recoveries, target compound matching quality, initial and continuing calibration data, internal standard area data and quantitation of results were evaluated in detail.

The analyses were performed acceptably, but necessitate a few qualifying statements. It is recommended that the reported results be used with the following qualifying statements. Any aspects of the data which are not discussed in this review should be considered quantitatively and qualitatively valid as reported.

AR300913

The ERM Group

1.2 Organic Qualifiers

- The detection limits for the semivolatile acid extractable compounds in both production well samples may be higher than reported because two or more acid surrogates were outside the quality control limits. Reextraction and reanalysis of the samples resulted in similar acid surrogate spike recoveries, confirming the presence of a matrix interference problem with the samples. Data has been reported on the data summary from the reextraction analyses if the compound was not present in the original analysis. It should also be noted that the reextractions were performed past the 40 CFR Part 136, 7 day extraction holding time. The initial extractions were within the allowable holding time.

- The presence of bis (2-ethylhexyl) phthalate in both the reextraction analyses of the procuction well samples is qualitatively questionable because of the presence of these compounds in the associated laboratory method blank. EPA protocol allows positive sample results that are less than or equal to 10 times the travel or method blank contamination levels of common laboratory contaminants such as phthalate esters to be considered qualitatively questionable. This has been indicated by placing a "B" next to the reported results on the attached data summary table.

- The reported detection limits for benzo (b) fluoranthene and bezno (k) fluoranthene for the reextraction analyses of the production well samples should be considered quantitative estimates because the percent difference (%D) between the initial calibration average response factor and the continuing calibration response factor exceeded 50%. No positive results were reported for this compound in either of the samples. This high %D indicates a lack of instrument stability for this compound.

- It should be noted that the tris (2-chloropropyl) phosphate ("tris") standards had three distinct peaks eluting closely together in sequence at an approximate retention time of 20 minutes. The mass spectrum of each of these peaks were identical, indicating the apparent presence of three individual tris isomers or three groups of tris isomers which co-elute. The first peak consistently had the highest response factor of approximately 0.3 (using d10-phenanthrene as the internal standard) with the next two peaks decreasing to about 0.15 and 0.03, respectively. The production well samples which had tris present also showed the distinct three peak chromatography pattern. Therefore, quantitation for tris in the production well samples was done using the first tris peak because it had the highest response factor. Quantitation using the other two peaks showed concentrations which were very similar. Quantitation using the total area of the three peaks and a single response factor calculated from the total area of the three peaks in the standard also showed little difference in the calculated concentration. A separate quantitation routine from the remainder of the semivolatile target compounds was created to quantitate tris.

- It should be noted that no semivolatile matrix spike samples were analyzed with the production well samples.

- The COD values for both production well samples are considered qualitatively questionable because of the presence of elevated COD levels in the blind travel blank (39 mg/l). This has been indicated by placing a "B" next to the results on the data summary table.

- As required by CLP protocols, all TIC's have been flagged with a "J" to indicate they are estimated quantitative values. ERM has reported on the data summary tables only those TIC's which were demonstrated not to be the result of laboratory contamination or instrument artifacts.

- As required by CLP protocols, all compounds which were qualitatively identified at a concentration below the CLP contract required detection limit have been flagged with a "J" to indicate they are quantitative estimates.

2.0 Inorganic Data

2.1 Introduction

The inorganic analyses of the 2 production well samples, associated MS and laboratory duplicate samples, and blind travel and method blanks were completed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for 2 elements, iron and manganese, according to the Contract Laboratory Program protocols specified in the Statement of Work for Inorganic Analyses (SOW 7/85). The samples were analyzed using Inductively Coupled Plasma emission (ICP) spectrometry. Additionally, total cyanide was analyzed for according to method 335.3 as referenced in "Methods for Chemical Analysis of Water and Wastes" (EPA-600/4-79-020 March 1983). The findings in this report are based on a review of all data required under the CLP for inorganic analyses. Quality assurance requirements for holding times, travel and method blank results, matrix spikes, laboratory duplicates, detection limits, initial and continuing calibrations, interference checks, serial dilution analyses and quantitation of results were evaluated in detail.

The analyses were performed acceptably, and do not require any qualifying statements.

2.0 Summary

The organic and inorganic analyses for the production well samples were performed acceptably but required a few qualifying statements. This analytical quality assurance review has identified the aspects of the the analytical data which have required qualifying statements. A support documentation package has been prepared for this quality assurance review and is filed with the New Castle Spill Site Remedial Investigation project file.

Report prepared by:

Lester J. Dupes — 15 July 1988
Lester J. Dupes
Quality Assurance Chemist
Date: 15 July 1988

David R. Blye
David R. Blye
Quality Assurance Manager
Date: 15 July 1988

ORIGINAL
(Red)

ATTACHMENT 1
SUMMARY OF SAMPLES FOR WHICH ANALYTICAL DATA WERE REVIEWED

Traffic Report Number	Location	Cambridge Laboratory Number
8336	PW-1 Static (Blind Blank)	8805213-01
8337	PW-1 60 minutes	8805213-02
8338	PW-1 23 hours	8805213-03

ORIGINAL (Red)

Analytical Results of Ground Water Samples Collected During Pump Test New Castle Spill Site

ERM T. R. No. Sample Location Sample Date Units	8337 PW-1 60 min 5/12/88 ug/l	8338 PW-1 23 hrs 5/13/88 ug/l
Volatile Organics		
1,2-Dichloroethene	3 J	
Trichloroethene	41	31
Tentatively Indentified Volatile Compounds		
Unknown	4 J	5 J
Semi Volatiles		
Bis(2-Ethylhexyl)Phthalate	4 B*	9 B*
Tentatively Indentified Semivolatile Compounds		
Unknown	14 J	16 J
Additional Semi Volatiles		
Tris(2-chloropropyl) Phosphate	520	420
Inorganics		
Iron	268	345
Manganese	3230	2960
COD mg/l	9.4 B	5.6 B
TOC mg/l	5.6	8.6
phenols mg/l		
cyanide mg/l		

Qualifiers:
"B" - This result is qualitatively questionable because the compound was detected in method and/or travel blanks at similar concentrations.
"J" - This result is an estimated concentration.
Blank spaces- indicate the compound was not detected.
"*" - This result is from a reextraction analysis.

APPROVED FOR RELEASE BY QUALITY ASSURANCE

David R. Blye 7/15/88

QA/QC MANAGER DATE

Analytical Quality Assurance Review
New Castle Spill Site
Remedial Investigation
Surface Water and
Sediment Samples
Collected 15 and 16
November 1988

4 January 1989

Prepared For:

The Witco Corporation
155 Tice Boulevard
Woodcliff Lake, N.J.

Prepared By:

Environmental Resources Management
855 Springdale Drive
Exton, PA 19341

File No. 310-06-04

New Castle Spill Site Remedial Investigation
Surface Water and Sediment Samples
Collected 15 and 16 November 1988
Analytical Quality Assurance Review

The following analytical quality assurance review is based on the review of all data for surface water and sediment samples collected on 15 and 16 November 1988 in association with the New Castle Spill Site Remedial Investigation. The samples that have undergone this quality assurance review are listed on Table 1. Data summary tables presenting the validated and qualified analytical results are attached at the end of this section.

All results have been validated or qualified according to general guidance provided in the documents entitled "Laboratory Data Validation Functional Guidelines for Evaluating Organic (and Inorganic) Analyses (USEPA)".

1.1 Organic Data

1.1.1 Introduction

Six surface water samples, six sediment samples and two travel blanks were analyzed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for trichlorothene according to the Contract Laboratory Program (CLP) volatile organic protocols specified in the Statement of Work for Organic Analysis (10/86 with revisions). An additional analysis for the compound tris(2-chloropropyl)phosphate, which is specific to the New Castle Spill Site was also performed by CLP protocols for semivolatile organic compounds by the addition of this compound to the semivolatile organic target compound library.

The findings offered in this report are based on a detailed review of the following criteria reported according to the Contract Laboratory Program deliverables format: holding times, blank analyses, surrogate compound recoveries, matrix spike compound recoveries and reproducibility, duplicate analyses, bromofluorobenzene (BFB) and decafluorotriphenylphosphine (DFTPP) mass tuning results, initial and continuing calibrations, consistency in internal standard integrations, quantitation of results, and qualitative mass spectral interpretation.

The organic analyses were performed acceptably, but require a qualifying statement. It is recommended that the qualified results only be utilized at an appropriate level of usability. Any data which are not qualified in this review are qualitatively and quantitatively valid as reported.

1.1.2 Organic Qualifiers

- All positive results for trichlorothene and tris(2-chloropropyl)phosphate, with the exception of tris(2-chloropropyl)phosphate in WS-2, were quantitated at levels below the method quantitation limits. Therefore, these results have been qualified with a "J" to indicate that they are quantitative estimates.

1.2 Inorganic Data

1.2.1 Introduction

Six surface water samples and two travel blanks were analyzed by Cambridge Analytical Associates of Boston, Massachusetts. Each sample was analyzed for total and dissolved iron and manganese, according to the CLP protocols specified in the Statement of Work for Inorganic Analyses (SOW 7/85). Also, six sediment samples were analyzed for total organic carbon (TOC) by EPA Method 415.1.

The findings offered in this report are based on a detailed review of the following criteria reported according to the Contract Laboratory Program (CLP) deliverables format: holding times, method blank results, matrix spikes, laboratory duplicates, detection limits, control samples, initial and continuing calibrations, interference checks, ICP serial dilution analyses, and quantitation of positive results.

The inorganic analyses were performed acceptably, but requires one qualifying statement. It is recommended that the qualified results only be utilized at an appropriate level of usability. Any data which are not qualified in this review are qualitatively and quantitatively valid as reported.

1.2.2 Inorganic Qualifiers

- The positive results for total iron and total manganese in all surface water samples should be considered quantitative estimates and have been qualified with a "J" on the data summary tables. The associated matrix spike recoveries for these analytes were outside the established percent recovery control limits.

2.0 Summary

The organic and inorganic analyses for these samples were performed acceptably, but required a few qualifying statements. This analytical quality assurance review has identified all aspects of the analytical data which have required qualifying statements. A support documentation package further detailing these findings has been filed with the New Castle Spill Site Remedial Investigation project file.

Report Prepared By:

Lester J. Dupes
Quality Assurance Chemist

1/4/89
Date

Approved By:

David E. Gallis
Senior Quality Assurance Chemist

1/4/89
Date

TABLE 1
NEW CASTLE SPILL SITE
SURFACE WATER AND SEDIMENT SAMPLING
SUMMARY OF SAMPLE DATA REVIEWED

ERM TRAFFIC #	SAMPLE LOCATION	DATE SAMPLED	CAMBRIDGE TCE # /TOC#	CAMBRIDGE TRIS #	CAMBRIDGE METALS #
13509	TRAVEL BLANK	11/15/88	8811206-01	8811206-01BX	8811206-01S
13510	WS-1	11/15/88	8811206-02	8811206-02BX	8811206-02S
13511	WS-2	11/15/88	8811206-03	8811206-03BX	8811206-03S
13512	WS-3	11/15/88	8811206-04	8811206-04BX	8811206-04S
13513	WS-4	11/15/88	8811206-05	8811206-05BX	8811206-05S
13514	WS-5	11/15/88	8811206-06	8811206-06BX	8811206-06S
13515	WS-6	11/15/88	8811206-07	8811206-07BX	8811206-07S
13516	SD-1	11/15/88	8811208-01	8811208-01BX	8811208-01S
13517	SD-2	11/15/88	8811208-02	8811208-02BX	8811208-02S
13518	SD-3	11/15/88	8811208-03	8811208-03BX	8811208-03S
13519	SD-4	11/15/88	8811208-04	8811208-04BX	8811208-04S
13520	SD-5	11/15/88	8811208-05	8811208-05BX	8811208-05S
13521	SD-6	11/15/88	8811208-06	8811208-06BX	8811208-06S
13615	TRAVEL BLANK	11/16/88	8811211-01		
13616	WS-6	11/16/88	8811211-02		
13617	WS-5	11/16/88	8811211-05		
13618	WS-4	11/16/88	8811211-06		
13619	WS-3	11/16/88	8811211-07		
13620	WS-2	11/16/88	8811211-08		
13621	WS-1	11/16/88	8811211-09		

Table 4-13
Analytical Results For Phase II Surface Water and Sediment Samples
New Castle Spill Site

ERM T. R. No.	13510	13511	13512	13513	13514	13515
Sample Location	WS-1	WS-2	WS-3	WS-4	WS-5	WS-6
Sample Date	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88
Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
trichloroethene						
Tris(2-chloropropyl)phosphate	3.09 J	5.37	4.37 J	1.15 J		
Total Metals						
Iron	494 J	6090 J	2070 J	1690 J	2140 J	1520 J
Manganese	90 J	2290 J	1480 J	705 J	391 J	402 J
ERM T. R. No.	13621	13620	13619	13618	13617	13616
Sample Date	11/16/88	11/16/88	11/16/88	11/16/88	11/16/88	11/16/88
Dissolved Metals						
Iron	338	51	37	45	45	22
Manganese	174	1980	206	163	71	47

Qualifier Codes:
J: This result should be considered a quantitative estimate.
Note: No concentration is entered for compounds which were not detected.

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DATE

Table 4-13 (cont.)
Analytical Results For Phase II Surface Water and Sediment Samples
New Castle Spill Site
(all soil results are dry weight corrected)

ERM T. R. No.	13516	13517	13518	13519	13520	13521
Sample Location	SD-1	SD-2	SD-3	SD-4	SD-5	SD-6
Sample Date	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88	11/15/88
Units	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg	ug/Kg
Percent Moisture for Organics	19%	54%	70%	66%	45%	40%
Percent Moisture for TOC	38%	51%	75%	64%	51%	49%
trichloroethene	3 J					
Tris(2-chloropropyl)phosphate			402 J	300 J		
TOC (ug/g)	13000	40000	82000	58000	54000	25000

Qualifier Codes:
J: This result should be considered a quantitative estimate.
Note: No concentration is entered for compounds which were not detected.

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QUALITY ASSURANCE
1/4/89
DATE

APPENDIX H

PERMEABILITY ANALYSIS OF CLAY UNIT AND PARTICLE ANALYSIS OF WETLAND SEDIMENT SAMPLES

5120 Butler Pike
Plymouth Meeting
Pennsylvania 19462
215-825-3000
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Woodward·Clyde Consultants

April 6, 1988
88C2099

Environmental Resource Management, Inc.
855 Springdale Drive
Exton, Pennsylvania 19341

Attention: Mr. Nicholas J. DeSalvo
RI Project Manager

Re: Laboratory Testing of Soils
ERM Inc. Job No. 310-06-01

Gentlemen:

Woodward-Clyde Consultants (WCC) is pleased to present herein the test results of the laboratory soil tests conducted for Environmental Resource Management Inc., Job No. 310-06-01. The soil samples were delivered to our laboratory by Environmental Resource Management, Inc. (ERM) on the March 20, 1988. The tests performed and the relevant procedures or standards used are as follows:

- Water Content — ASTM D 2216
- Grain Size Determinations — ASTM D 422
- Permeability Tests:
  1. USACE EM 1110-2-1906
  2. Bjerrum & Huder "Measurement of the Permeability of Compacted Clays," Proceeding of the 4th International Conference on Soil Mechanics & Foundation Engineering, Vol. 1, 1957.

PHYSICAL PROPERTIES

Table 1 presents a list of the soil samples received and tested. For grain-size calculations, a specific gravity of 2.50 was assumed for the organic soils tested. Grain-size distribution curves and logs of tubes are presented in Appendices A & B, respectively.

PERMEABILITY TESTS

Permeability tests were conducted on all the Shelby tubes. The tests were performed using WCC-designed "closed-loop, constant-volume, variable-head" triaxial permeameter system. In the absence of field data and instructions, all the specimens were consolidated to an effective stress of about 10 pounds per square inch (psi) and then incrementally back-pressured to 100 psi to ensure an acceptable degree of saturation

(95 percent or better). The effective consolidation pressure used is lower than the in situ consolidation stress of the samples. Deaired Plymouth Meeting tap water was used as permeant and an initial hydraulic gradient of about 25 was utilized to initiate flow through the specimen. Results of the permeability tests are presented in Table 2.

It has been our pleasure working with you on this project. If you have any questions, or if we can be of further service, please call.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

Enrique N. Manuel

Enrique N. Manuel
Laboratory Director

ENM/tjr/14C

Tables

WGA-RP-4

PROJECT: ENVIRONMENTAL RESOURCE MANAGEMENT

TABLE 1

PROJECT No. 88C2099

SUMMARY OF LABORATORY TEST RESULTS

BORING and SAMPLE No	DEPTH (feet)	CLASSIFICATION	SPECIAL TESTS	NATURAL WATER CONTENT (%)	ATTERBERG LIMITS		UNCON COMPRESS		UNIT DRY WGT (pcf)	SPECIFIC GRAVITY	GRAIN SIZE		OPT MOIST	CONSOLID	TRIAXIAL			
					LIQUID LIMIT	PLASTIC LIMIT	STRESS (tsf)	STRAIN (%)			SIEVE	HYDR			UU	CIU	CELL PRESSURE (psi)	BACK PRESSURE (psi)
GS-1											*	*						
GS-5											*	*						
GS-6											*	*						
MW-1	36.0 - 38.0		K	*					*									
PW-1	30.0 - 32.0		K	*					*									
MW-3	33.5 - 35.5		K	*					*									
MW-4	39.5 - 41.5		K	*					*									
MW-5	37.5 - 39.5		K	*					*									

* See Test Curves

Woodward-Clyde Consultants

AR300930

Environmental Resource Management, Inc.
88C2099

April 7, 1988

TABLE 2
SUMMARY OF PERMEABILITY TEST

Boring No.	Sample Depth, ft	$M.C._o$ %	γ_d pcf	e_o	S_o %	$M.C._f$ %	S_f %	K cm/sec
MW-1	36.5	19.5	111.3	0.591	93.8	19.5	99.4	1.46×10^{-8}
PW-1	30.6	18.1	113.1	0.567	90.6	16.9	99.8	1.68×10^{-8}
MW-3	34.1	17.7	112.7	0.572	88.2	17.4	99.6	4.57×10^{-8}
MW-4	40.1	16.1	118.7	0.492	93.0	15.9	100.0	1.79×10^{-8}
MW-5	38.1	19.4	111.8	0.585	94.1	20.1	97.4	4.83×10^{-8}

Where:

M.C. = Initial or final water content

γ_d = Initial dry density

e = Initial void ratio

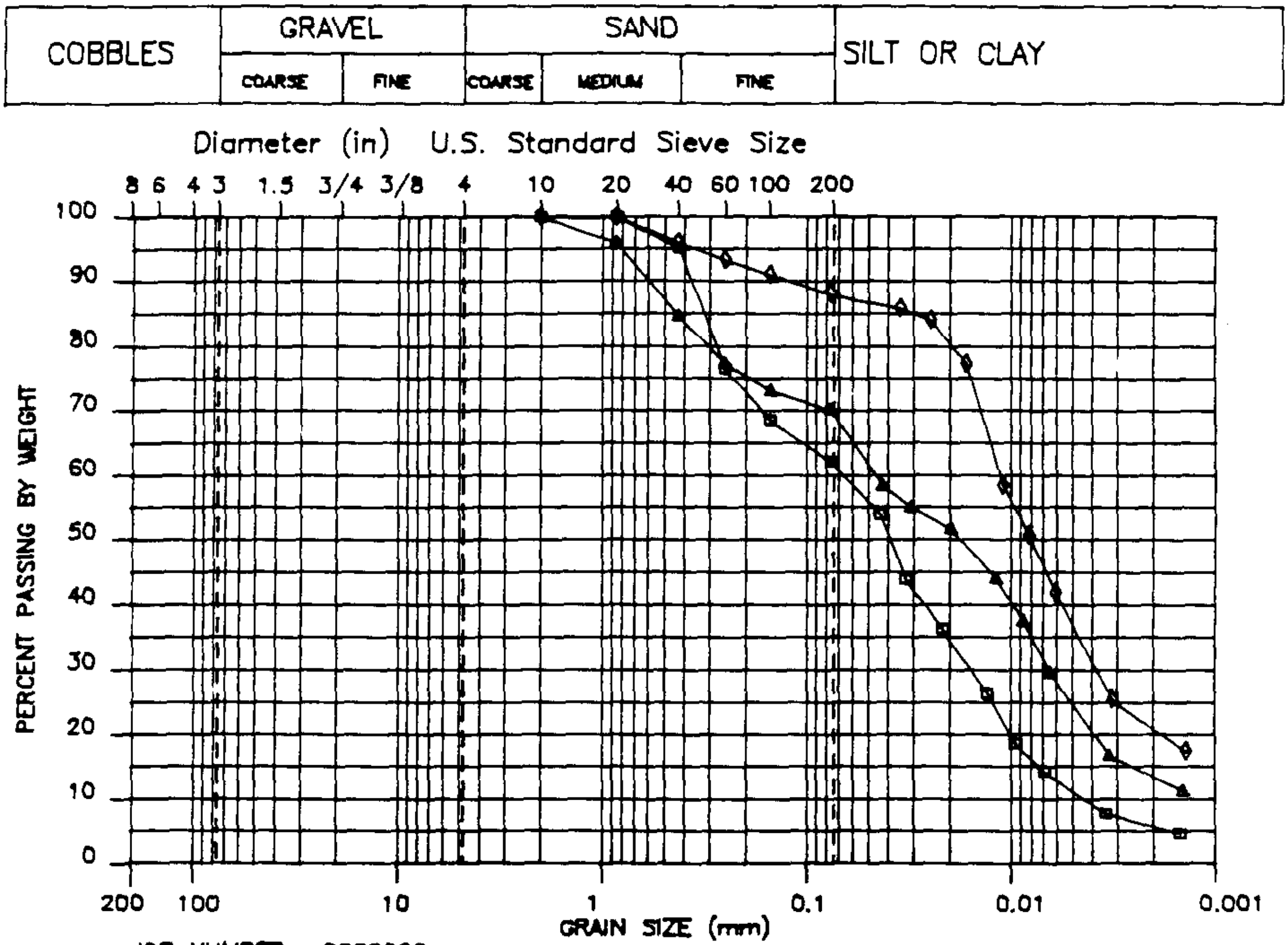
S = Initial or final degree of saturation

K = Coefficient of permeability corrected to 20°C

Note: Specific gravity was assumed for all the Shelby tube samples.

Appendix A

WOODWARD-CLYDE CONSULTANTS
PLYMOUTH MEETING LABORATORY
PARTICLE-SIZE DISTRIBUTION



JOB NUMBER : 88C2099

JOB NAME : ENVIRONMENTAL RESOURCE MANAGEMENT

SYM	BORING#	SAMPLE#	DEPTH	DESCRIPTION	W(%)	W_L (%)	W_P (%)
□	GS-1			GRAY ORGANIC FINE SANDY CLAYEY SILT.			
Δ	GS-5			GRAY ORGANIC FINE SANDY CLAYEY SILT.			
◊	GS-6			GRAY ORGANIC CLAYEY SILT.			

AR300933

Appendix B

WCC L-107
(6/75)

LABORATORY LOG OF TUBE SAMPLE

Proj No. 88C2099 Proj Eng. EM Date Opened 4/1/88 By VT

Boring No. MW-1 Sample No. 1 Depth 36.0 To 38.0

Tag No.

Tube Seals	Wax	Mech	Good	Fair	Loose	Leaking Water	Leaking Soil
Top		✓	✓				
Bottom		✓	✓				

Cutting Edge	Sharp	Dull	Nicked <Mod>	Dented	Neck Down <OK>
	✓				✓

Remarks

	Tube Scale Ft	Jar No.	Sample Use	Depth in Ground, ft	DESCRIPTION OF SOIL AND REMARKS
VOID	0.0				
	0.2				.45 Top Void
	0.4				
	0.6				Gray, Brown Sa si Clay Firm to hard
	0.8		K=.50'		
	1.0				
	1.2				
	1.4				
	1.6				
	1.8				
	2.0				
	2.2				
	2.4				

Measured length of tube = 2.5 ft Recovery 2.05 ft

Type Tube 3.0" O.D. Brass Steel Shelby 2.875

I.D. Cutting edge(D_e) ____ in. Tube(D_i) ____ in.

Inside Clearence Ratio = $\frac{D_i - D_e}{D_e} \times 100 =$ ____ %

Total Unit Weight of Soil		
Wgt. soil + tube	7799.6 gm	Total Unit Weight by
Wgt. tube	2220.6 gm	CUTTING EDGE (D_e) ____ TUBE (D_i) ____ AVE ____
Wgt. wet soil	____ gm	γ_t ____ ____ ____ lb/ft^3
Calculated by		Reviewed by

AR300935

WCC L-107
(6/75)

LABORATORY LOG OF TUBE SAMPLE

Proj No. 88C2099 Proj Eng. E.M. Date Opened 4/1/88 By VT

ring No. PW-1 Sample No. – Depth 30.0 To 32

Tag No.

Tube Seals	Wax	Mech	Good	Fair	Loose	Leaking Water	Leaking Soil
Top		✓		✓		✓	
Bottom		✓	✓				

Cutting Edge	Sharp	Dull	Nicked < Mod >	Dented	Neck Down < OK >
	✓				✓

Remarks

	Tube Scale Ft	Jar No.	Sample Use	Depth in Ground, ft	DESCRIPTION OF SOIL AND REMARKS
Void	0.0				
	0.2				
	0.4				.85 Top Void
	0.6				
	0.8				
	1.0				Top -.3 Red Brown sa si / si sand soft
	1.2	K=.60'			
	1.4				.3-.95. Red Brown sa si clay - Firm
	1.6				
	1.8				
	2.0				.95 - Botton Gray sa si clay - Firm
	2.2				
	2.4				

Measured length of tube = 2.5 ft Recovery ______ ft

Type Tube 3" O.D. Brass Steel Shelby 2.875 I.D. { Cutting edge(D_e) ______ in. Tube(D_i) ______ in.

Inside Clearence Ratio = $\frac{D_i - D_e}{D_e} \times 100 =$ ____%

Total Unit Weight of Soil			
Wgt. soil + tube	6908.0 gm	Total Unit Weight by	
Wgt. tube	2370.3 gm	CUTTING EDGE (D_e)	TUBE (D_i)	AVE
Wgt. wet soil	______ gm	γ_t ______	______	______ lb/ft^3
Calculated by	______	Reviewed by ______	

AR300936

WCC L-107
(6/75)

LABORATORY LOG OF TUBE SAMPLE

Proj No. 88C2099 Proj Eng. EM Date Opened 4/1/88 By VT

Boring No. MW-3 Sample No. – Depth 33.5 To 35.5

Tag No.

Tube Seals	Wax	Mech	Good	Fair	Loose	Leaking Water	Leaking Soil
Top		✓	✓				
Bottom		✓	✓				

Cutting Edge	Sharp	Dull	Nicked <Mod.>	Dented	Neck Down <OK>
	✓				✓

Remarks

	Tube Scale Ft	Jar No.	Sample Use	Depth in Ground, ft	DESCRIPTION OF SOIL AND REMARKS
Void	0.0				
	0.2				
	0.4				.7 Top Void
	0.6				
	0.8				Gray, Brown sa. si. clay - soft - Firm
	1.0		K=.55		
	1.2				
	1.4				
	1.6				
	1.8				
	2.0				
	2.2				
	2.4				

Measured length of tube = 2.5 ft Recovery 1.8 ft

Type Tube 3" O.D. Brass (Steel) Shelby 2.875 I.D. { Cutting edge(D_e) ____ in. Tube(D_i) ____ in.

Inside Clearence Ratio = $\frac{D_i - D_e}{D_e} \times 100 =$ ____ %

Total Unit Weight of Soil				
Wgt. soil + tube 7431.2 gm	Total Unit Weight by			
Wgt. tube 2431.3 gm	CUTTING EDGE (D_e)	TUBE (D_i)	AVE	
Wgt. wet soil ____ gm	γ_t ____	____	____	lb/ft^3
Calculated by ____	Reviewed by ____			

AR300937

WCC L-107
(6/75)

LABORATORY LOG OF TUBE SAMPLE

Proj No. ________ Proj Eng. EM Date Opened 4/1/88 By VT

ring No. MW-4 Sample No. — Depth 39.5 To 41.5

Tag No. ________

Tube Seals	Wax	Mech	Good	Fair	Loose	Leaking Water	Leaking Soil
Top	✓		✓				
Bottom	✓		✓				

Cutting Edge	Sharp	Dull	Nicked <Mod>	Dented	Neck Down <OK>
	✓				✓

Remarks ________

	Tube Scale Ft	Jar No.	Sample Use	Depth in Ground, ft	DESCRIPTION OF SOIL AND REMARKS
Void	0.0				
	0.2				.5 top Void
	0.4				
	0.6				Top -.3 GRAY si SAND soft
	0.8				
	1.0	K=.60			GRAY sa si CLAY - FIRM to hard (.3-1.0)
	1.2				
	1.4				
	1.6				1.0 - Bottom
	1.8				Red, GRAY mottLED CLAY
	2.0				
	2.2				
	2.4				

Measured length of tube = 2.5 ft Recovery 2.0 ft

Type Tube 3.0 O.D. Brass Steel Shelby 2.875

I.D. { Cutting edge(D_e) ______ in. ; Tube(D_i) ______ in.

Inside Clearence Ratio = $\frac{D_i - D_e}{D_e} \times 100 =$ ____ %

Total Unit Weight of Soil			
Wgt. soil + tube	7925.1 gm	Total Unit Weight by	
Wgt. tube	2229.7 gm	CUTTING EDGE (D_e) ____ TUBE (D_i) ____	AVE ____
Wgt. wet soil	______ gm	γ_t ______ ______ ______	lb/ft^3
Calculated by	______	Reviewed by ______	

AR300938

WCC L-107
(6/75)

LABORATORY LOG OF TUBE SAMPLE

Proj No. 876209 Proj Eng. E.M. Date Opened 4/1/88 By VT

ring No. MW-5 Sample No. - Depth 32.5 To 37.5

Tag No.

Tube Seals	Wax	Mech	Good	Fair	Loose	Leaking Water	Leaking Soil
Top	✓		✓				
Bottom	✓		✓				

Cutting Edge	Sharp	Dull	Nicked <Mod.>	Dented	Neck Down <OK>
			✓		✓

Remarks

	Tube Scale Ft	Jar No.	Sample Use	Depth in Ground, ft	DESCRIPTION OF SOIL AND REMARKS
Void	0.0				
	0.2				
	0.4				.8 Top Void
	0.6				
	0.8				Brown Si sand - soft Top - .4
	1.0				
	1.2		✓=.60'		Brown Sa Si Clay - Firm .4 - 1.0
	1.4				
	1.6				
	1.8				Gray Sa Cly Si/Silty 1.0 - Bottom
	2.0				
	2.2				
	2.4				

Measured length of tube = 2.5 ft Recovery 1.7 ft

Type Tube ← 3" O.D. Brass Steel Shelby 2.875 I.D. { Cutting edge(D_e) ____ in. Tube(D_i) ____ in.

Inside Clearence Ratio = $\frac{D_i - D_e}{D_e} \times 100 =$ ____ %

Total Unit Weight of Soil			
Wgt. soil + tube	7205.2 gm	Total Unit Weight by	
Wgt. tube	2305.6 gm	CUTTING EDGE (D_e) / TUBE (D_i) / AVE	
Wgt. wet soil	____ gm	γ_t ____ ____ ____ lb/ft^3	
Calculated by		Reviewed by	

AR300939

NTH / RUSSELL ASSOCIATES
A Division of Neyer, Tiseo & Hindo, Ltd.
Consulting Engineers and Geologists
860 Springdale Drive, Exton, Pennsylvania 19341 215 524-2300 FAX 215 524-2317

December 8, 1988

ENVIRONMENTAL RESOURCES MANAGEMENT, INC.
855 Springdale Drive
Exton, PA 19341

Attention: Mr. Jeff Gerlach

Reference: Laboratory Test Results
Witco Project
New Castle, DE

Gentlemen:

At your request, we have conducted laboratory testing of soil samples from the Witco Project. These samples were provided by Environmental Resources Managment, Inc. Six sediment samples were delivered to our Exton, PA laboratory for a determination of particle size distribution via hydrometer.

All laboratory testing was performed in accordance with American Society of Testing Materials (ASTM) standards. The grain size distribution curves for the six samples are presented in Appendix A. The test data are shown in Appendix B for your information.

We appreciate this opportunity to be of service to you. If you have any questions regarding the laboratory testing, please contact us.

Very truly yours,

NTH/RUSSELL ASSOCIATES

Paul F. Marano

Paul F. Marano, P. E.

PFM/JS

APPENDIX A

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

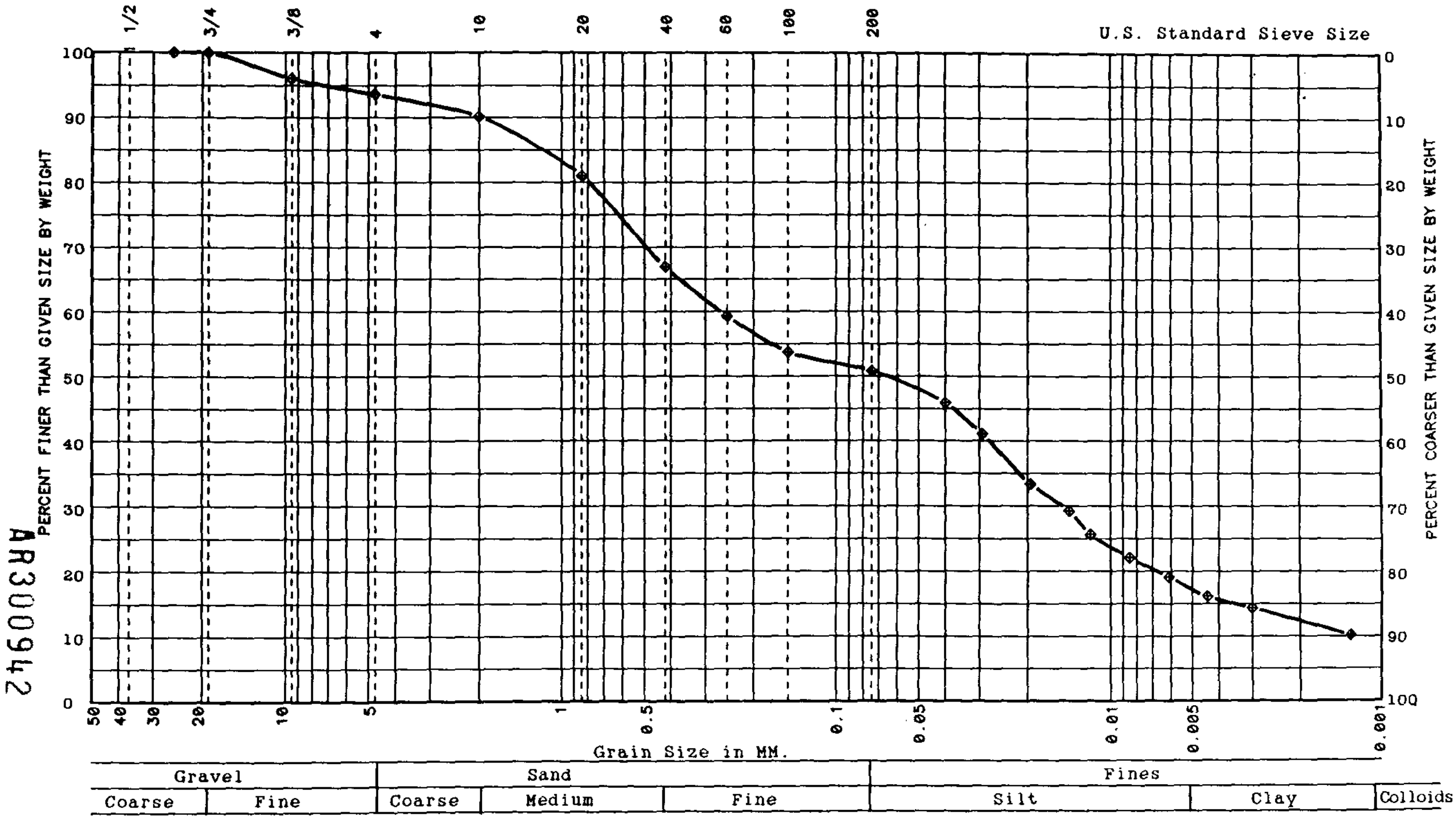
Project No. 08466 GP Lab Sample No. ______ Source ______

Project Location New Castle, DE For Witco Project

Boring No. ______ Field Sample No. SD -1G Sample Depth ______ Sample Elev. (Tip) ______

Sample Description Dark brown silty fine to coarse SAND, traces clay and fine gravel, organic.

Sampled By ______ Date ______ Tested By B.S. Date 11-28-88 Check By S.G.



AR300942

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

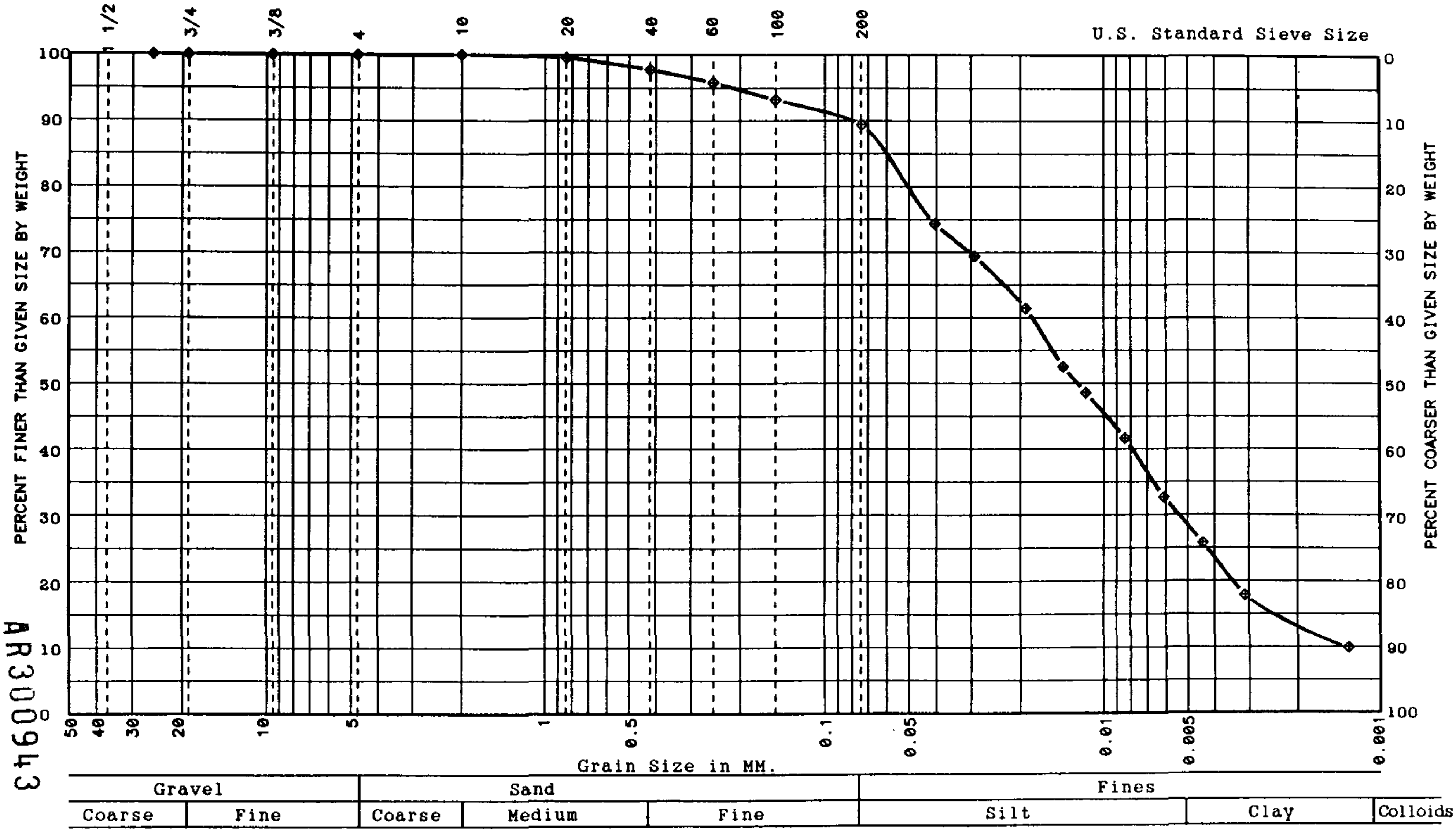
Project No. 08466 GP Lab Sample No. ______ Source ______

Project Location New Castle, DE For Witco Project

Boring No. ______ Field Sample No. SD - 2G Sample Depth ______ Sample Elev. (Tip) ______

Sample Description Dark brown clayey SILT, trace fine to medium sand, highly organic

Sampled By ______ Date ______ Tested By B.S. Date 11-28-88 Check By S.G.



AR300943

PN

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

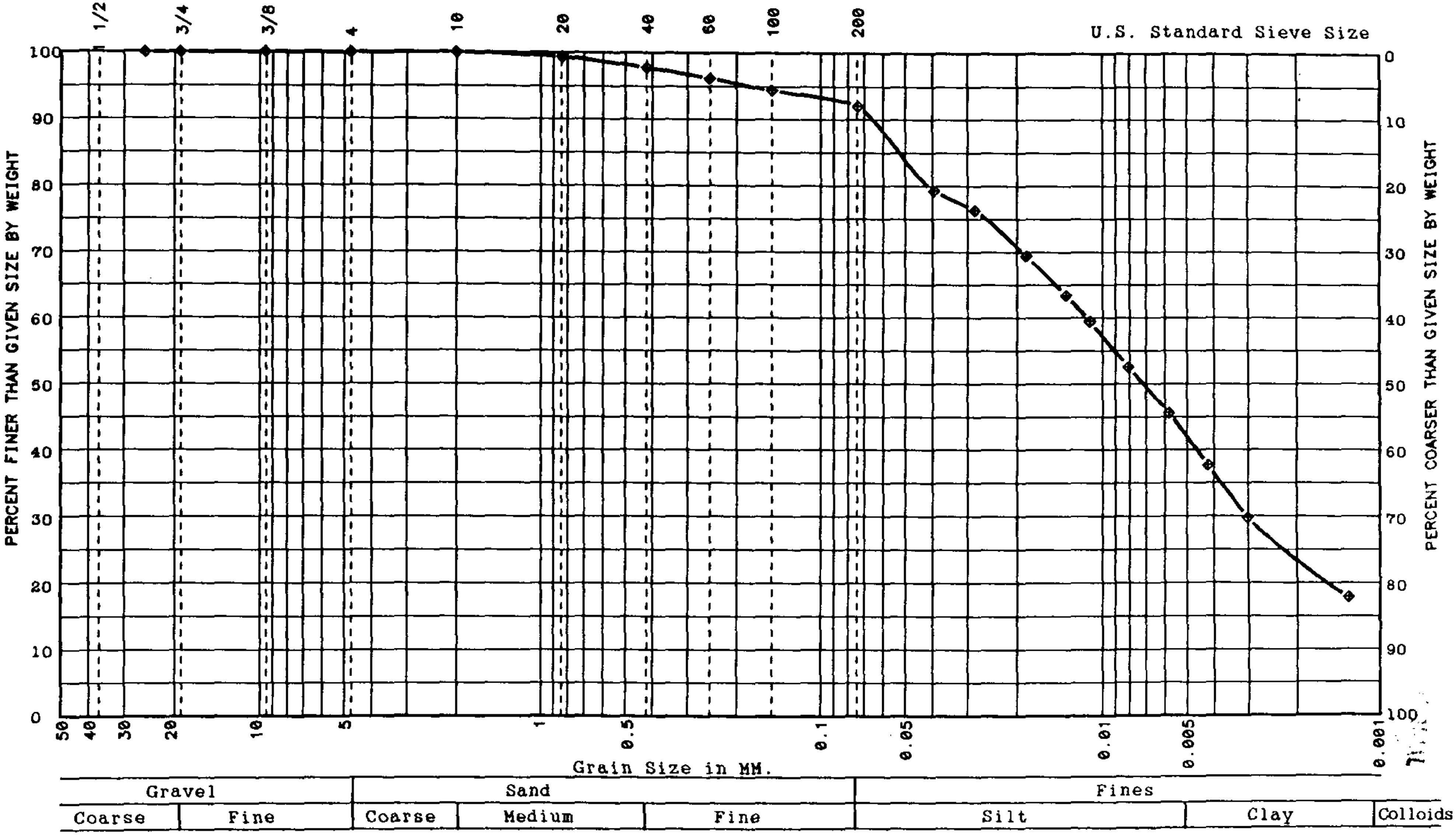
Project No. 08466 GP Lab Sample No. ____ Source ____

Project Location New Castle, DE For Witco Project

Boring No. ____ Field Sample No. SD-3G Sample Depth ____ Sample Elev. (Tip) ____

Sample Description Dark gray clayey SILT, trace fine to medium sand, highly organic

Sampled By ____ Date ____ Tested By B.S. Date 11-28-88 Check By S.G.



AR300944

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

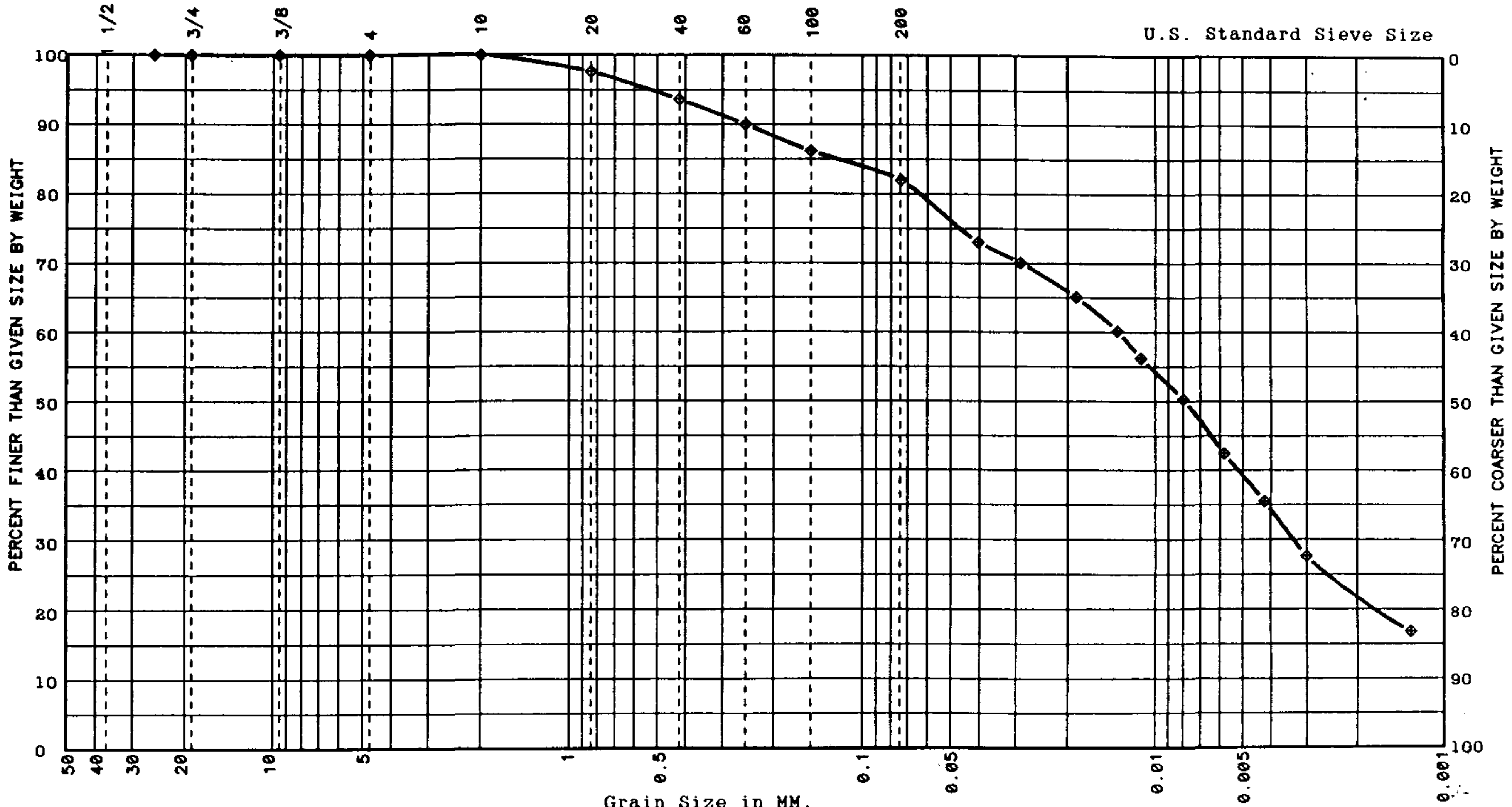
Project No. 08466 GP Lab Sample No. ______ Source ______

Project Location New Castle, DE For Witco Project

Boring No. ______ Field Sample No. SD - 4G Sample Depth ______ Sample Elev. (Tip) ______

Sample Description Dark gray sandy SILT, little clay, highly organic

Sampled By ______ Date ______ Tested By B.S. Date 11-28-88 Check By S.G.



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

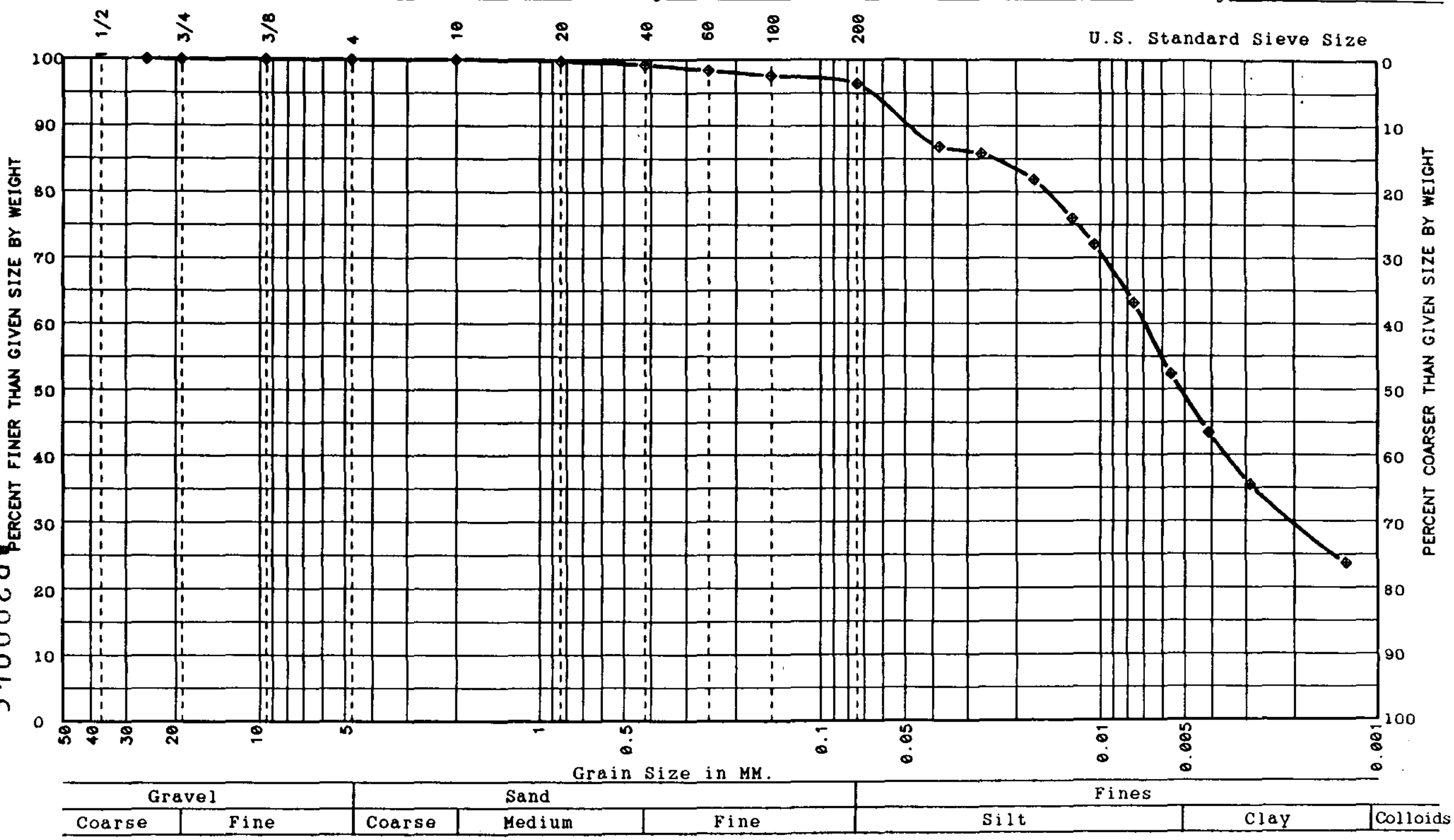
Project No. 08466 GP Lab Sample No.______ Source______

Project Location New Castle, DE For Witco Project

Boring No.______ Field Sample No. SD - 5G Sample Depth______ Sample Elev. (Tip)______

Sample Description Dark gray clayey SILT, trace fine sand, slightly organic

Sampled By______ Date______ Tested By B.S. Date 11-28-88 Check By S.G.



AR300946

NEYER, TISEO & HINDO, LTD.

GRAIN SIZE DISTRIBUTION CURVE

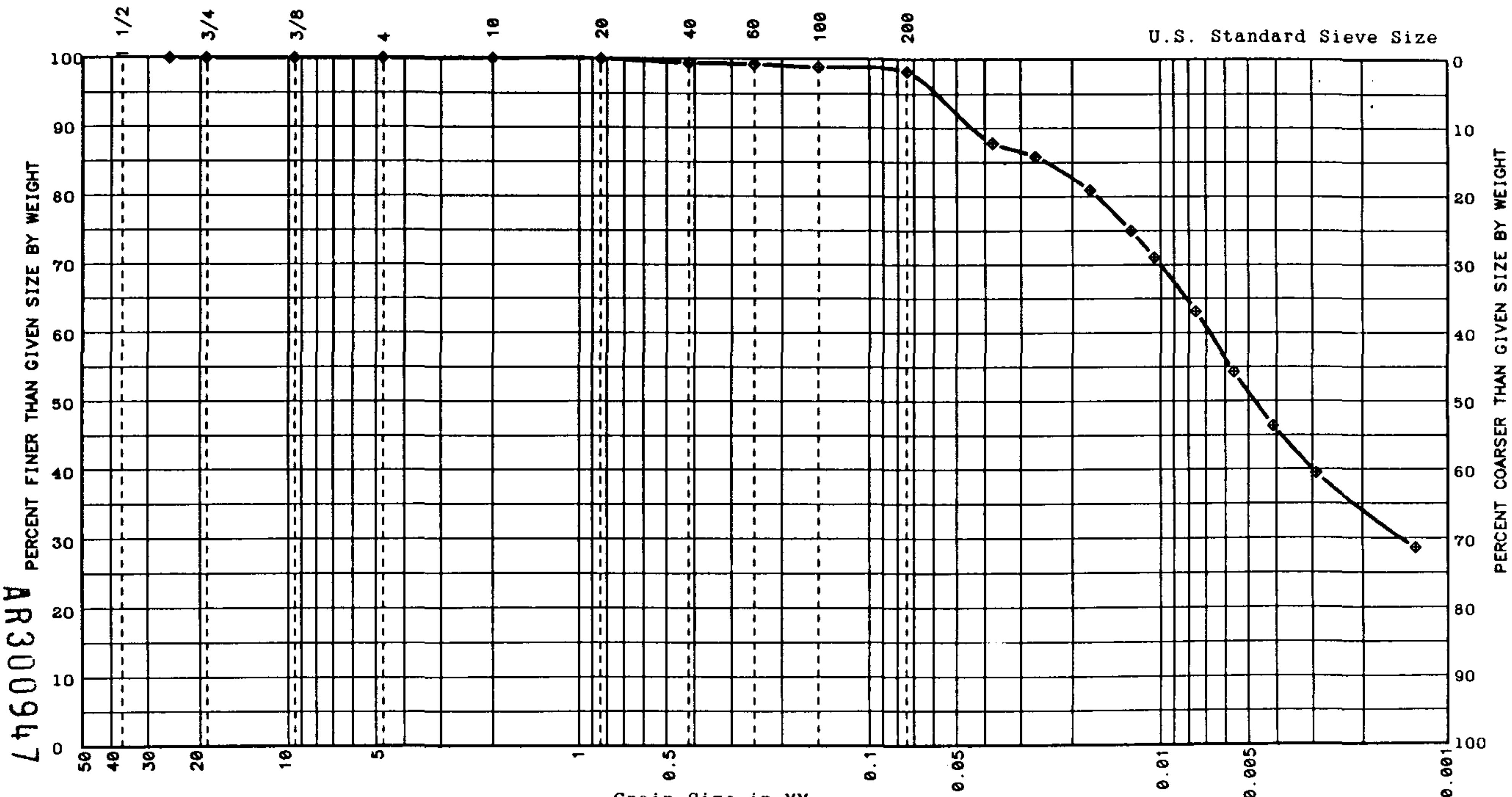
Project No. 08466 GP Lab Sample No. ______ Source ______

Project Location New Castle, DE For Witco Project

Boring No. ______ Field Sample No. SD - 6G Sample Depth ______ Sample Elev. (Tip) ______

Sample Description Dark gray clayey SILT, trace fine sand, organic

Sampled By ______ Date ______ Tested By B.S. Date 11-28-88 Check By S.G.



Gravel		Sand			Fines		
Coarse	Fine	Coarse	Medium	Fine	Silt	Clay	Colloids

AR300947

APPENDIX B

PROJECT NUMBER: 08466 GP PROJECT NAME: ERM - WITCO LAB TEST
TEST BORING NUMBER: SAMPLE NUMBER: SD 10 SAMPLE DEPTH: 0.00
DESCRIPTION: SAT. DK BR ~~CLAYEY SILT~~, ~~SOME SAND~~ TR. clay & GRAVEL W/ORGANIC MATTER
silty sand

SIEVE ANALYSIS OF MATERIAL (W1 = 226.40 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	9.0	4.0	96.0
4	4.75	14.5	6.4	93.6
10	2.00	22.1	9.8	90.2
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	7.7	10.3	81.0
40	.420	19.4	25.9	66.9
60	.250	25.7	34.3	59.3
100	.150	30.4	40.5	53.7
200	.074	32.8	43.7	50.8

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.690 CORR. A=0.991 WT. OF SAMPLE W3= 75.00 GR

TIME	TEMP C	HYDROMETER ORIG	RW	READ R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTED %PASSING
1.	22.0	43.0	4.5	38.5	50.9	0.01315	9.2	0.0400	45.9
2.	22.0	39.0	4.5	34.5	45.6	0.01315	9.9	0.0293	41.1
5.	22.0	32.5	4.5	28.0	37.0	0.01315	11.0	0.0195	33.4
10.	22.0	29.0	4.5	24.5	32.4	0.01315	11.5	0.0141	29.2
15.	22.0	26.0	4.5	21.5	28.4	0.01315	12.0	0.0118	25.6
30.	22.0	23.0	4.5	18.5	24.4	0.01315	12.5	0.0085	22.1
60.	22.0	20.5	4.5	16.0	21.1	0.01315	12.9	0.0061	19.1
120.	22.0	18.0	4.5	13.5	17.8	0.01315	13.3	0.0044	16.1
250.	23.0	16.0	4.0	12.0	15.9	0.01300	13.7	0.0030	14.3
1440.	21.0	13.5	5.0	8.5	11.2	0.01330	14.1	0.0013	10.1

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-21-88 CHECKED BY

PROJECT NUMBER: 08466 GP PROJECT NAME: ERM - WITCO LAB TESTING
TEST BORING NUMBER: SAMPLE NUMBER: SD - 2G SAMPLE DEPTH: 0.00
DESCRIPTION: SAT. DK BR CLAYEY SILT TR FINE SAND , ~~SOME~~ VERY ORGANIC

SIEVE ANALYSIS OF MATERIAL (W1 = 120.20 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	0.0	0.0	100.0
4	4.75	0.0	0.0	100.0
10	2.00	0.0	0.0	100.0
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	0.2	0.4	99.6
40	.420	1.1	2.2	97.8
60	.250	2.1	4.2	95.8
100	.150	3.4	6.8	93.2
200	.074	5.3	10.6	89.4

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.690 CORR. A=0.991 WT. OF SAMPLE W3= 50.00 GR

TIME	TEMP C	HYDROMETER READ ORIG	RW	R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTED %PASSING
1.	21.5	42.5	5.0	37.5	74.3	0.01322	9.3	0.0404	74.3
2.	21.5	40.0	5.0	35.0	69.4	0.01322	9.7	0.0292	69.4
5.	21.5	36.0	5.0	31.0	61.4	0.01322	10.4	0.0191	61.4
10.	21.5	31.5	5.0	26.5	52.5	0.01322	11.1	0.0140	52.5
15.	21.5	29.5	5.0	24.5	48.6	0.01322	11.5	0.0116	48.6
30.	21.5	26.0	5.0	21.0	41.6	0.01322	12.0	0.0084	41.6
60.	22.0	21.5	5.0	16.5	32.7	0.01315	12.8	0.0061	32.7
120.	22.0	18.0	5.0	13.0	25.8	0.01315	13.3	0.0044	25.8
250.	22.5	14.0	5.0	9.0	17.8	0.01307	14.0	0.0031	17.8
1440.	21.5	10.0	5.0	5.0	9.9	0.01322	14.7	0.0013	9.9

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-28-88 CHECKED BY SG

AR300950

PROJECT NUMBER: 09466-GP PROJECT NAME: ERM - WITCO LAB TEST
TEST BORING NUMBER: SAMPLE NUMBER: SD-30 SAMPLE DEPTH: 0.00
DESCRIPTION: SAT. DK GRAY CLAYEY SILT TR FINE to med SAND, ~~SOME~~ VERY ORGANIC

SIEVE ANALYSIS OF MATERIAL (W1 = 80.20 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	0.0	0.0	100.0
4	4.75	0.0	0.0	100.0
10	2.00	0.0	0.0	100.0
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	0.3	0.6	99.4
40	.420	1.1	2.2	97.8
60	.250	1.9	3.8	96.2
100	.150	2.8	5.6	94.4
200	.074	4.0	8.0	92.0

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.690 CORR. A=0.991 WT. OF SAMPLE W3= 50.00 GR

TIME	TEMP C	HYDROMETER READ ORIG	RW	R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTED %PASSING
1.	21.5	45.0	5.0	40.0	79.3	0.01322	8.9	0.0395	79.3
2.	21.5	43.5	5.0	38.5	76.3	0.01322	9.2	0.0283	76.3
5.	21.5	40.0	5.0	35.0	69.4	0.01322	9.7	0.0185	69.4
10.	21.5	37.0	5.0	32.0	63.4	0.01322	10.2	0.0134	63.4
15.	21.5	35.0	5.0	30.0	59.5	0.01322	10.6	0.0111	59.5
30.	21.5	31.5	5.0	26.5	52.5	0.01322	11.1	0.0081	52.5
60.	22.0	28.0	5.0	23.0	45.6	0.01315	11.7	0.0058	45.6
120.	22.0	24.0	5.0	19.0	37.7	0.01315	12.4	0.0042	37.7
250.	22.5	20.0	5.0	15.0	29.7	0.01307	13.0	0.0030	29.7
1440.	21.5	14.0	5.0	9.0	17.8	0.01322	14.0	0.0013	17.8

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-28-88 CHECKED BY ________

AR300951

PROJECT NUMBER: 08466-GP PROJECT NAME: ERM-WITCO LAB TEST
TEST BORING NUMBER: SD - 40 SAMPLE DEPTH: 0.00
DESCRIPTION: SAT. DK GREY ~~SILTY CLAY TR FINE SAND~~ VERY ORGANIC
sandy silt w/ little clay

SIEVE ANALYSIS OF MATERIAL (W1 = 97.40 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	0.0	0.0	100.0
4	4.75	0.0	0.0	100.0
10	2.00	0.0	0.0	100.0
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	1.2	2.4	97.6
40	.420	3.2	6.4	93.6
60	.250	5.0	10.0	90.0
100	.150	6.9	13.8	86.2
200	.074	9.0	18.0	82.0

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.710 CORR. A=0.987 WT. OF SAMPLE W3= 50.00 GR

TIME	TEMP C	HYDROMETER READ ORIG	RW	R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTED %PASSING
1.	21.5	42.0	5.0	37.0	73.0	0.01314	9.4	0.0403	73.0
2.	21.5	40.5	5.0	35.5	70.1	0.01314	9.7	0.0289	70.1
5.	21.5	38.0	5.0	33.0	65.1	0.01314	10.1	0.0187	65.1
10.	21.5	35.5	5.0	30.5	60.2	0.01314	10.5	0.0135	60.2
15.	21.5	33.5	5.0	28.5	56.2	0.01314	10.8	0.0112	56.2
30.	22.0	30.5	5.0	25.5	50.3	0.01307	11.3	0.0080	50.3
60.	22.0	26.5	5.0	21.5	42.4	0.01307	12.0	0.0058	42.4
120.	22.0	23.0	5.0	18.0	35.5	0.01307	12.5	0.0042	35.5
250.	22.5	19.0	5.0	14.0	27.6	0.01300	13.2	0.0030	27.6
1440.	21.5	13.5	5.0	8.5	16.8	0.01314	14.1	0.0013	16.8

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-28-88 CHECKED BY

AR300952

PROJECT NUMBER: 08466 GP PROJECT NAME: ERM - WITCO LAB TEST
TEST BORING NUMBER: SAMPLE NUMBER: SD - 5G SAMPLE DEPTH: 0.00
DESCRIPTION: DK GRAY CLAYey [redacted] SILT TR FINE SAND, SLIGHTLY ORGANIC

SIEVE ANALYSIS OF MATERIAL (W1 = 201.90 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	0.0	0.0	100.0
4	4.75	0.0	0.0	100.0
10	2.00	0.0	0.0	100.0
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	0.1	0.2	99.8
40	.420	0.4	0.8	99.2
60	.250	0.8	1.6	98.4
100	.150	1.2	2.4	97.6
200	.074	1.8	3.6	96.4

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.710 CORR. A=0.987 WT. OF SAMPLE W3= 50.00 GR

TIME	TEMP C	HYDROMETER READ ORIG	RW	R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTED %PASSING
1.	21.5	49.0	5.0	44.0	86.8	0.01314	8.3	0.0378	86.8
2.	21.5	48.5	5.0	43.5	85.8	0.01314	8.3	0.0268	85.8
5.	21.5	46.5	5.0	41.5	81.9	0.01314	8.7	0.0173	81.9
10.	21.5	43.5	5.0	38.5	76.0	0.01314	9.2	0.0126	76.0
15.	21.5	41.5	5.0	36.5	72.0	0.01314	9.5	0.0105	72.0
30.	22.0	37.0	5.0	32.0	63.2	0.01307	10.2	0.0076	63.2
60.	22.0	31.5	5.0	26.5	52.3	0.01307	11.1	0.0056	52.3
120.	22.0	27.0	5.0	22.0	43.4	0.01307	11.9	0.0041	43.4
250.	22.5	23.0	5.0	18.0	35.5	0.01300	12.5	0.0029	35.5
1440.	21.5	17.0	5.0	12.0	23.7	0.01314	13.5	0.0013	23.7

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-28-88 CHECKED BY ________

PROJECT NUMBER: 08466 GP PROJECT NAME: ERM - WITCO LAB TEST
TEST BORING NUMBER: SAMPLE NUMBER: SD - 6G SAMPLE DEPTH: 0.00
DESCRIPTION: DK GRAY CLAY, [redacted] SILT TR FINE SAND, ORGANIC

SIEVE ANALYSIS OF MATERIAL (W1 = 201.70 GR)

SIEVE NUMBER	SCREEN OPENING (MM)	CUMULATIVE RETAINED WEIGHT (GRAM)	CUMULATIVE RETAINED (PERCENT)	CUMULATIVE PASSING (PERCENT)
1	1.00"	0.0	0.0	100.0
3/4	.75"	0.0	0.0	100.0
3/8	.375"	0.0	0.0	100.0
4	4.75	0.0	0.0	100.0
10	2.00	0.0	0.0	100.0
** SIEVE ANALYSIS FROM HYDROMETER (W3) **				
20	.840	0.0	0.0	100.0
40	.420	0.3	0.6	99.4
60	.250	0.4	0.8	99.2
100	.150	0.6	1.2	98.8
200	.074	0.9	1.8	98.2

HYDROMETER ANALYSIS OF MATERIAL PASSING NO. 10 SIEVE

HYDROMETER NO. 1 SP. GR.=2.710 CORR. A=0.987 WT. OF SAMPLE W3= 50.00 GR

TIME	TEMP C	HYDROMETER READ ORIG	RW	R	%PASSING	CORRECTION COEFFICIENT K	L CM	CORRECTED DIAMETER MM	CORRECTE %PASSIN
1.	21.5	49.5	5.0	44.5	87.8	0.01314	8.2	0.0376	87.8
2.	21.5	48.5	5.0	43.5	85.8	0.01314	8.3	0.0268	85.8
5.	21.5	46.0	5.0	41.0	80.9	0.01314	8.8	0.0174	80.9
10.	21.5	43.0	5.0	38.0	75.0	0.01314	9.2	0.0126	75.0
15.	21.5	41.0	5.0	36.0	71.0	0.01314	9.6	0.0105	71.0
30.	22.0	37.0	5.0	32.0	63.2	0.01307	10.2	0.0076	63.2
60.	22.0	32.5	5.0	27.5	54.3	0.01307	11.0	0.0056	54.3
120.	22.0	28.5	5.0	23.5	46.4	0.01307	11.6	0.0041	46.4
250.	22.5	25.0	5.0	20.0	39.5	0.01300	12.2	0.0029	39.5
1440.	21.5	19.5	5.0	14.5	28.6	0.01314	13.1	0.0013	28.6

*** NOTE THE TIME SEQUENCE ON THIS OUTPUT ***
RECALCULATE CORRECTED PARTICLE DIAMETERS IF TIMES DIFFER !

D = K * SQRT (L/T)

%PASSING=(100*R*A)/W3

TESTED BY: BS DATE: 11-28-88 CHECKED BY ________

AR300954

APPENDIX I

CORRESPONDENCE RELATED TO THE NATURAL RESOURCES INQUIRY

Environmental Resources Management, inc.

855 Springdale Drive • Exton, Pennsylvania 19341 • (215) 524-3500 • Telex 4900009249

13 June 1988

Mr. Ron Vickers
Delaware DNREC
Natural Heritage Program
89 Kings Highway
P. O. Box 1401
Dover, Delaware 19903

Dear Mr. Vickers:

Environmental Resources Management, Inc. (ERM) has been retained to conduct an environmental assessment of the former Witco Chemical Company site and the surrounding wetland habitat located on Wilmington Avenue (Route 9), approximately 1 mile north of New Castle, Delaware. A location map is attached (from the USGS quadrangle; Wilmington South, DE). Part of the environmental assessment requires information as to the presence on or near the site of any rare, threatened, or endangered species of plants or animals, species of special concern, and/or habitat of special concern.

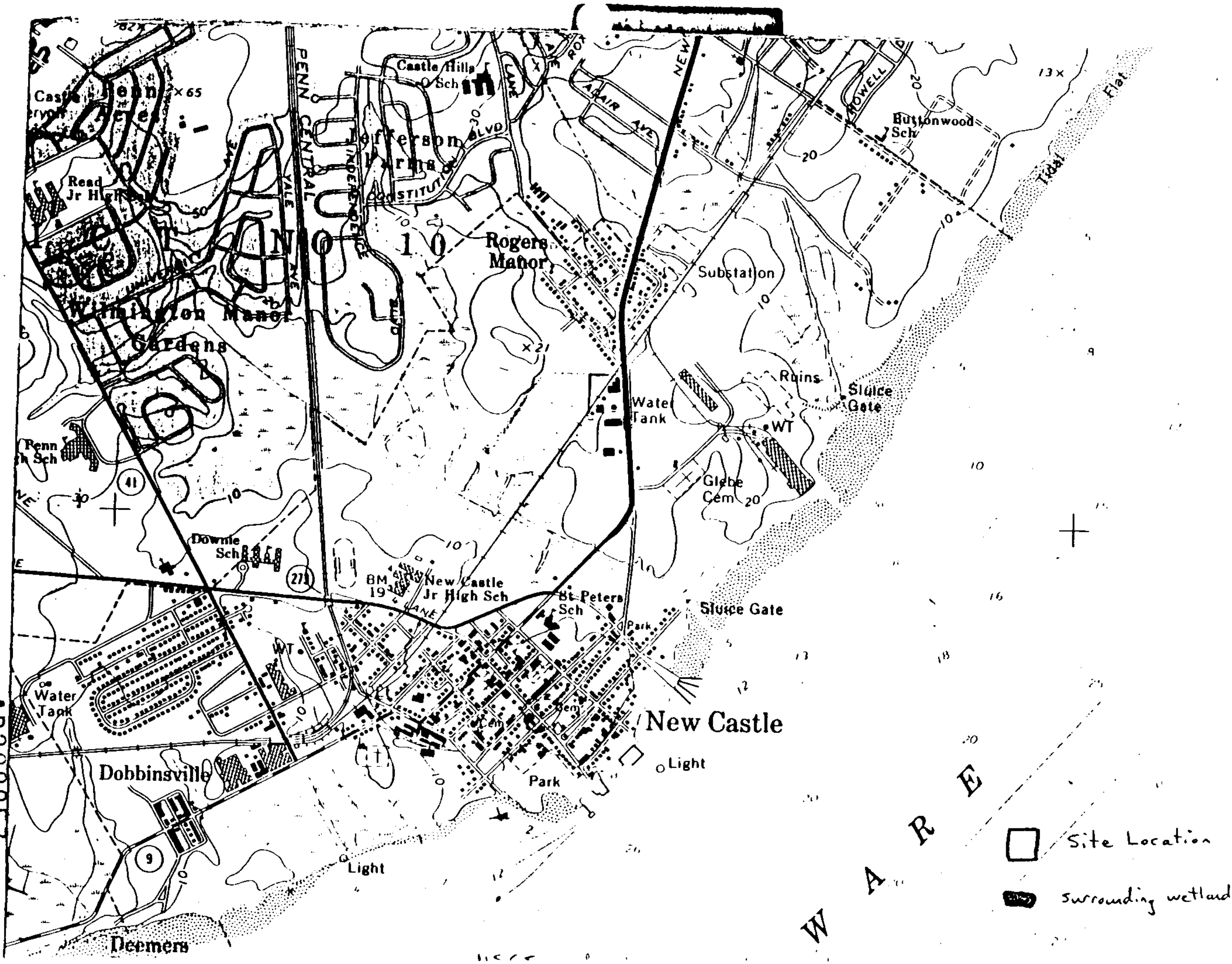
I request a search of your data base(s) in relation to the above request. Your expeditious handling of this report will be appreciated. If I can provide any other information, please contact me at (215) 524-3636.

Sincerely,

Jeff Gerlach

Jeff Gerlach

JG:kss



New Castle
Castle Hills Sch
Jefferson Farms
Rogers Manor
Wilmington Manor Gardens
Read Jr High Sch
Penn Sch
Downie Sch
New Castle Jr High Sch
St Peters Sch
Substation
Water Tank
Ruins
Sluice Gate
WT
Glebe Cem
Buttonwood Sch
Tidal Flat
Dobbinsville
Deemers
Light
Park
PENN CENTRAL
YALE AVE
ADAIR AVE
HOWELL
INDEPENDENCE
CONSTITUTION
BLVD
LANE
NEW
WARE
Site Location
surrounding wetland

AR300957

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF PARKS & RECREATION
89 KINGS HIGHWAY
PO BOX 1401
DOVER, DELAWARE 19903

September 30, 1988

Mr. Jeff Gerlach
Environmental Resources Management, Inc.
855 Springdale Drive
Exton, PA 19341

Dear Mr. Gerlach:

Attached is a copy of a letter I sent you on July 27, 1988 in reference to the former Witco Chemical Company site north of New Castle, Delaware. The information and response are still the same. Our office has historical records for 4 species of special concern in the area. We would be glad to do a heritage inventory for plants and animals on a contract basis.

If I can be of further assistance, please feel free to contact me at 736-5285.

Sincerely,

Ron Vickers

Ron Vickers, Chief
Natural Heritage Program

RV:jhb
Attachment

DELAWARE PLANT SPECIES OF SPECIAL CONCERN
HISTORICAL RECORDS FOR THE WITCO CHEMICAL COMPANY SITE

Apocynum cannabinum	dogbane
Limnobium spongia	American frog's-bit
Ranunculus pensylvanicus	bristly crowfoot
Scutelaria galericulata	hooded skullcap

CRITERIA FOR DETERMINING STATE RANK

S1 = Typically 5 or fewer occurrences, very few remaining individuals, acres, or miles of stream or some factor of its biology making it especially vulnerable in Delaware.

S2 = Typically 6 to 20 occurrences, few remaining individuals, acres, or miles of stream, or factors demonstrably making it very vulnerable in Delaware.

S3 = Typically 21 to 100 occurrences, limited acreage, or miles of stream in Delaware.

S4 = Apparently secure in Delaware.

S5 = Demonstrably secure in Delaware.

SH = Histoically known from Delaware, but not seen in the past 15 years.

SX = Apparently extirpated from Delaware.

SE = Exotic, not native to Delaware.

SR = State Report only, no verified specimens known from Delaware.

SU = Status in Delaware is unknown.

SN = Regularly occurring, usually migratory. Does not typically breed in Delaware, but may pass through twice a year, or may remain in the winter.

Nomenclature follows Kartez and Kartez (1980) Synonymized Checklist of the Vascular Flora of the United States, Canada, and Greenland.

5/88 LT

Environmental Resources Management, inc.

855 Springdale Drive • Exton, Pennsylvania 19341 • (215) 524-3500 • Telex 4900009249

13 December 1988

Mrs. Janice Thomas
Delaware DNREC
Div. Fish and Wildlife
P.O. Box 1401
Dover, DE 19903

Dear Mrs. Thomas:

Environmental Resources Management, Inc., (ERM) has been retained to conduct an environmental assessment of the former Witco Chemical Company site and the surrounding wetland habitat located on Wilmington Avenue (Route 9), approximately 1 mile north of New Castle, Delaware. A location map is attached (from the USGS quadrangle; Wilmington South, DE). Part of the environmental assessment requires information as to the presence on or near the site of any rare, threatened, or endangered species of animals, species of special concern, and/or habitat of special concern.

I request a search of your data base(s) in relation to the above request. Your expeditious handling of this report will be appreciated. If I can provide any other information, please contact me at (215) 524-3636.

Sincerely,

Jeff Gerlach

Jeff Gerlach

JG:aek

L

NONGAME WILDLIFE, ENDANGERED SPECIES, NATURAL AREAS PRESERVATION FUND

DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENTAL CONTROL
89 KINGS HIGHWAY, P.O. BOX 1401, DOVER, DELAWARE 19903

December 21, 1988

Mr. Jeff Gerlach
Environmental Resources Management, Inc.
855 Springdale Drive
Exton, PA 19341

Dear Mr. Gerlach:

To the best of my knowledge there are no threatened or endangered species in the location of the former Witco Chemical Company site.

If you have any further questions feel free to contact me at (302)736-4782.

Sincerely,

Janis E. Thomas

Janis E. Thomas
Nongame and Endangered Species
Coordinator

JET/mh

GIVE A WILD GIFT

AR300962

EPA REGION III
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOC ID ~155230
PAGE # —

IMAGERY COVER SHEET
UNSCANNABLE ITEM

SITE NAME The New Castle Spill Site, Final Remedial Investigation Vol. I

OPERABLE UNIT —

ADMINISTRATIVE RECORDS- SECTION — VOLUME —

REPORT OR DOCUMENT TITLE —

—

DATE OF DOCUMENT April 1988

DESCRIPTON OF IMAGERY Plate 1 Compounds/Constituents Identified in Ground Water, New Castle Spill Site

NUMBER AND TYPE OF IMAGERY ITEM(S) 1 oversized map

EPA REGION III
SUPERFUND DOCUMENT MANAGEMENT SYSTEM

DOC ID 155230
PAGE # —

IMAGERY COVER SHEET
UNSCANNABLE ITEM

SITE NAME The New Castle Spill Site New Castle DE, Final Remedial Investigation Vol. II

OPERABLE UNIT —

ADMINISTRATIVE RECORDS- SECTION — VOLUME —

REPORT OR DOCUMENT TITLE —

—

DATE OF DOCUMENT March 1988

DESCRIPTON OF IMAGERY Plate 2 Compounds / Constituents Identified in Soils New Castle Spill Site

NUMBER AND TYPE OF IMAGERY ITEM(S) 1 oversized map

PAGE 300965 THROUGH 300982 LEFT INTENTIONALLY BLANK